LIFE

THOMAS TELFORD.

MAN

LIFE

OF

THOMAS TELFORD,

CIVIL ENGINEER,

WRITTEN BY HIMSELF;

CONTAINING

DESCRIPTIVE NARRATIVE

OF HIS

PROFESSIONAL LABOURS:

WITH

A FOLIO ATLAS OF COPPER PLATES.

EDITED BY

JOHN RICKMAN,

ONE OF HIS EXECUTORS;

WITH A

PREFACE, SUPPLEMENT, ANNOTATIONS, AND INDEX.

LONDON:

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PREFACE.

More than three years having elapsed since the death of Mr. Telford, in the beginning of September 1834, the first care of the Editor must be to explain the cause of delay in the appearance of this volume, especially as it is known to many that Mr. Telford himself had made arrangements for proceeding with the publication, in which he foresaw no difficulty.

The present volume originated very naturally when Mr. Telford began to withdraw himself from undertaking new professional engagements, and, from a growing infirmity of deafness, felt himself uncomfortable in any mixed company. In this predicament, it was obvious to suggest to him, that, in his intended transition from activity to leisure, he might yet do good service to the public, without too much fatigue to himself, if by degrees he renewed acquaintance with all his accumulated papers, making such a selection from them as, aided by his own recollections, might display to the public all the great works executed under his superintendence, and all the improvements introduced by him during the third part of a century of extensive practice in his profession.

Mr. Telford listened to this suggestion with much complacency, saying, that he had been thinking of the same thing, and had begun to arrange his papers; but that he felt himself out of the habit of composing accurately for public perusal; moreover, that as the work must be illustrated by many expensive engravings, and he might die before it was completed, he hesitated in resolving to undertake it. These objections were easily overcome, by promising him aid in the correction of his manuscript, if that should be necessary; and by undertaking that labour should not be wanting to make the book and its expensive plates available to the public, if he provided for that object in his Will.

Mr. Telford was advised to indite his work in some degree biographically, writing in the first person, as more agreeable to the reader, easier to himself, and not requiring classification of subjects; often a fruitless labour, in which no man can precisely satisfy himself, and which may be advantageously supplied for the convenience of the reader by a good Index to any volume, in whatever manner the materials may be arranged for publication.

Thus encouraged, Mr. Telford became eager in his task, and proceeded with unexpected diligence, transcribing and correcting his first draft throughout. He also engaged his friend, Mr. Turrell, a very ingenious engraver, to work on the copper-plates, urging forward his industry by payment of a fixed sum on production of every Proof impression. Mr. Telford held it to be entirely necessary for the due completion of the work, to retain the publication in his own power, and he engaged

a printer and a publisher (who have well justified his confidence), relying on Mr. Turrell for the more difficult task of perfecting all the copper-plates, and of intercourse with the tradesmen who must be employed to furnish materials and labour for the printed impressions.

As Mr. Turrell had already sent to Mr. Telford fifty-eight Proof impressions from copper-plates, and others were ready in lithograph; the latter was justified in supposing himself not precipitate in proceeding to print the book slowly and deliberately, with such improvements and additions, especially in the Appendix matter, as might occur to him. His arrangements as to Paper, Type and number of copies, were all decided by himself previously to his decease; so that his Executors have exercised no further discretion than in rejecting the lithographs, as unsuitable to the engravings which appear in the Atlas. The dimensions of this Atlas will be deemed by many too large for convenience; but Mr. Telford was always favourable to a large scale, as capable of distinct admeasurement in all its parts, and leaving no room for doubt or expensive recourse to the object itself, of which the exact dimensions may be hereafter required. Profit, from publication was not in Mr. Telford's contemplation; he anticipated a very different result, and herein his Executors have gone as far as was deemed justifiable in fulfilling the known intentions and expectation of the deceased.

After Mr. Telford's death, Mr. Turrell, no doubt, made some progress in perfecting the plates of which he had furnished proofs to Mr. Telford, and employed his establishment in commencing the rest; but, unfor-

tunately for the work and for the Editor, Mr. Turrell was visited with a violent disease, or rather succession of diseases, which incapacitated him from personal exertion, and even from superintendence, and terminated in his death, in September 1835, after six months' confinement to a sick-bed. Mr. Turrell left no successor in his business, and his widow was under the necessity of employing on the Telford plates the person who had been the chief assistant in Mr. Turrell's labours. In this state of the affair control was impossible, so that the plates could not be obtained till the month of June 1837, and then in a state which was pronounced to be unfit for the press. Thus has been explained that the present volume would, in all probability, have been in the hands of the public two years since, had not the illness and subsequent death of Mr. Turrell paralysed the progress of the Editor,—who now dismisses a subject wearisome to the reader, although necessary for his own justification.

The reader will naturally expect, in addition to Mr. Telford's own Narrative, a SUPPLEMENT which shall afford details of his death and character, and of such incidents of his life as are either casually omitted by him, or are such as a modest man does not willingly record of himself. Such a SUPPLEMENT will be found at the end of Mr. Telford's Narrative; and the reader may be assured that due diligence has been exerted in augmenting the Appendix articles, now increased by about one-third in number beyond what Mr. Telford had actually collected for that purpose; but he had intended to augment them, and several of his surviving friends (it will be seen) have not withheld their assistance,

especially such as extends the Narrative from the time of Mr. Telford's decease to the present day. But it has not been found possible, nor indeed could it be expected of any Editor, that the references to these or other Appendix articles, should be so precise as if Mr. Telford himself had carried this volume through the press, with all the Appendix articles ranged in order before him; so that in some instances (especially where the articles are numerous on one subject) the Capital Letter only, not the Number, appears; but to compensate for this defect, the Table of Contents prefixed to the Appendix exhibits references backward to the text, as also forward to the article itself.

A few plates have been added to the Atlas; especially that of the Conway Bridge (No. 78), with some part of the surrounding scenery, copied by permission of Mr. W. A. Provis, from his Historical Account of the construction of the Menai Bridge:—Also, the design (No. 83) for a Suspension Bridge at Runcorn Gap; and another design (No. 77) for a suspended centering over the Menai Strait, whereby an iron arch might have been made to supersede the now existing Chain Bridge; whether with advantage or not, must be left to the opinion of the public, till a comparison can be fairly instituted. A map (No. 58) exhibiting the locality of all Highland improvements; and a map (No. 34) of the Nene Outfall, one of the most successful of Mr. Telford's professional operations, have also been added, as necessary for reference. In the Plate (numbered 67.) appears the section and plan of a Polish road, very instructive, as exhibiting at one view the perfection at which Mr. Telford had arrived in road-making in the years preceding 1825; but as this

road is not mentioned elsewhere by Mr. Telford, the reader must here be told, that, on this occasion (not for the first time), the Russian government applied to Mr. Telford for his advice in constructing a road between Warsaw and the frontier of Russia, at Briesc; its direction is east and west, and the inscription on the medal struck on its completion estimates its extent at 178 wersts, or about 120 English miles; nor does the novelty of a Polish road made of broken flints escape notice.*

The Plate No. 1, which affords reference to the locality of all Mr. Telford's professional labours in Great Britain, is not mentioned in the subsequent part of this volume; and it is proper here to remark upon it, that the attention of the Admiralty having been called to the course of the tides around our island, they issued a circular to the coast-guard officers, with instructions for contemporaneous observations in the summers of 1834 and 1835; and afterwards referred those voluminous documents to the Rev. William Whewell, who methodized the whole, and has published in the Transactions of the Royal Society the result of his Researches on the tides; and the Editor thought that a fair opportunity ought not to be lost of exhibiting the most striking of these results on a Map, which, having been prepared for inland purposes, left the outline of the coast open for the insertion of this kind of infor-

* On the obverse of the medal is represented a very solid mile-stone, inscribed ÆRE PUBLICO SILICE STRATA; around this is inscribed, ALEX. I. P. F. V. CAES. AUG. IMP. T. RUS. REG. POL. JUSSU. On the reverse is a female figure seated on a bridge, with a carriage-wheel and corn-stalk (emblems of plenty insured by easy conveyance?). The inscription around her, A VARSOVIA STAD. CLXXVIII. On the exergue, VIA BRESTIENSIS.

mation; which cannot be thought alien from the studies of civil engineers, who often have occasion to refer to the subject of harbours, and therein of tides. The Editor is gratified in adding, that Mr. Whewell has perused, and with approbation, the short inscription on this map, indicating the precautions necessary for accurate calculation of the time of high-water. The inquiry has also led to acquaintance with an instrument of much merit for accurate observation of the range of the tides, and the figure and description of it are inserted in Appendix (Z.) for imitation when required.

One of the intended plates (No. 28) is omitted; it would have exhibited a remarkably large Skew Bridge (a bridge not at right angles with its canal or river); and with it was to have appeared, in the same plate, an old bridge of that kind thrown over the street, near the entrance of New College, Oxford, by Warden Nicholas, in 1673. But when a sketch of the construction of this arch was desired, it was unattainable, because, within the last fifty years, the soffit has been covered with plaster, and the curious construction of the masonry concealed. The span of this small arch is twelve feet; its height, over the roadway covered by it, about fifteen feet; the extent lengthwise over the road, twenty-four feet; and its deflexion from a right angle with the road, about twenty-five degrees. Nor could the plan of the Birmingham Canal Skew Bridge be readily obtained; and thus the intended plate (which was of subordinate importance) does not appear in the Atlas.

The annotations subjoined to the text are not unfrequent; they are mostly explanatory of words or phrases of a technical description; and a vast number of short notes has been avoided, by inserting an analogous word or phrase in the text, where it might not otherwise be understood by the general reader; the Editor deeming it part of his office to translate or expound all words in such manner that no previous unacquaintance with masonry, carpentry, earth-work or drainage, should be an impediment to the reader who wishes thoroughly to understand the scope and design of all the great operations described by Mr. Telford. With some peril, no doubt, all this has been attempted, as one class of readers may smile at superfluous information, or discover that it is not so correct as personal experience might afford; but it has been thought better to hazard such exposure to criticism, than to incur the culpable neglect of not conveying, or endeavouring to convey, information to those readers who have just right to complain if an expensive book is placed in their hands, which cannot be understood without such frequent occasion for reference as oftener terminates in fatigue, than in obtaining all the information sought.

Other notes, more extensive, have been inserted without hesitation, where they seemed in any degree pertinent to the subject mentioned in the text; distant analogies and remote combinations being those which enlarge the scope of human knowledge, and which ought never to be slighted, when they present themselves for notice and application.

In the course of editing this volume, and answering without reserve such questions as have occurred concerning its Contents, regret has sometimes been excited, in that nothing was to be said of some designs in which Mr. Telford took, or was supposed to take, a prominent part. Of these, the most remarkable is said to have been a projected canal across the Isthmus of Darien; concerning which, however, nothing appears in his papers, and nothing remarkable transpired in his conversation; and the suggestion of his concern in this project may have been ascribed to him on slight grounds, by those who wished thus to recommend it in the year 1825, when the spirit of speculation was so excessive, that mere reference to any map of the American hemisphere was deemed evidence of the practicability of so grand a proposal.

Another scheme in which Mr. Telford was really engaged might certainly have found a place in the Volume and Atlas, had not obstacles occurred. Early in Mr. Telford's Highland transactions, he became acquainted with Mr. Nimmo, at that time Master of the Academy of Inverness, who in his summer vacation was employed to trace the boundaries of the Highland counties, and did so with a degree of intelligence, and display of general knowledge, which much recommended him to the notice of the Commissioners for Highland Roads and Bridges. Mr. Nimmo was thus encouraged to change his occupation in life, and become a civil engineer, in which character he was mostly employed in Ireland, Mr. Telford being always friendly to him, and more than once going to Ireland on his behalf. Mr. Nimmo often visited Liverpool, in his journeys between London and Dublin, and

observing the variable shoals and sand-banks which obstruct direct access to the estuary of the Mersey, he formed a grand scheme for a broad and deep ship-canal, extending about seven miles from the south side of that estuary to the estuary of the Dee, near Helbrè Isle, where it was found that a safe entrance to the canal might be constructed, and thus a fair way from the sea to Liverpool secured, with the advantage of such unexampled wharfage accommodations as the increasing commerce of Liverpool seemed to require, in assuming the character of the Western Commercial Capital of Great Britain. The project was magnificent, and in the year 1827 Mr. Telford was called in to sustain, by his authority, the proposal of Mr. Nimmo; and he entered upon the investigation with the utmost zeal; but suddenly the affair was terminated on the payment of a large sum of money, by the Corporation of Liverpool, to a person who had secured right of pre-emption of the only possible position of the northern entrance of the intended canal. Mr. Telford, extremely disgusted in being made the instrument of a transaction which in his opinion was premeditated and collusive, seems to have destroyed all his documents relative to this grand scheme, and never spoke of the cause of failure without singular indignation; so that this short notice of the affair, as regarding Mr. Telford, must suffice.

It is commonly said, that when once a Civil Engineer has acquired reputation by his known merit, he has little leisure to procure or record knowledge collateral to his immediate occupation; and although no man ever so extensively practised or so much improved road-making

as Mr. Telford, he was not accustomed to enter into any retrospect of the rise and progress of that useful art, nor of the effect of various wheel-carriages on the surface of roads.

From the date of the provincial military roads made in Britain and elsewhere by the Romans, skilful road-making sunk into the general oblivion of the dark ages, and was not revived till the beginning of the last century, when, under the name of Turnpikes,* good roads began to be made between large towns, and were paid for, without injustice, by tolls imposed on the traveller; these roads had become so numerous in the beginning of the reign of George the Third,† that the legislature was called upon to protect them by general regulations, which had

* A turnpike, or barrier studded with pikes, so as to preclude a passage, unless opened by the gate-keepers, is the *chevaux de frise* of military language; the expedient adopted in the Low Country wars by the people of Friezeland, in their defect of cavalry, to enable them to withstand the heavy cavalry of the well-appointed armies by which they were assailed.

† The progress of Turnpike legislation may be thus stated; from 1700 to 1710, twelve Turnpike Acts received the Royal Assent; from 1710 to 1720, twenty-one Acts; from 1720 to 1730, seventy-one Acts; from 1730 to 1740, thirty-one Acts; from 1740 to 1750, twenty-nine Acts; thus far existed one hundred and sixty-nine Turnpike Acts. From 1750 to 1760, one hundred and eighty-five Acts were added; from 1760 to 1770, one hundred and seventy-five Acts; so that five hundred and thirty such Acts existed in the year 1770. These Acts were limited to twenty-one years' duration, the Legislature presuming that tolls might not continue to be always necessary; but the clerks of the several trusts always take care not to pay the creditors of the road lest the trust should cease, and their office become extinct. Moreover, the renewal of the Turnpike Act at the end of the term is profitable employment for the clerk; but since the year 1830, the term is prolonged to thirty-one years. These renewals are of course omitted in the above enumeration of Turnpike Acts. At present, the Turnpike Trusts in existence exceed eleven hundred. The total Debt of the Turnpike Trusts is £.8,500,000; of which £.1,000,000 is unpaid Interest. They pay £.300,000 Interest annually, upon Bond Debts amounting to £.7,100,000. Their annual Income from Tolls, &c. is £. 1,800,000; their Expenditure in making, maintaining and improving roads is £. 1,064,000; in Management £. 135,000. Payment of debts, interest, and incidental expenses must explain the rest.

become in some degree necessary, because the tolls were chargeable according to the number of wheels, without regard to the weight carried on the cart or waggon; and turnpike-roads were cut into ruts by this kind of advantage acquired by the carrier, in proportion as he damaged the road.

The remedy proposed in the pamphlets on this subject, which swarmed between the years 1760 and 1770, was by enforcing an established proportion between the breadth of wheel, the weight of load, and the toll levied; and Acts of Parliament were obtained accordingly, in the years 1767, 1770 and 1773; but the advocates for broad wheels laboured under a mistake in their confidence that newly-laid materials can be fixed in position by any degree of direct pressure; it is possible indeed to crush much of the exterior surface of the hardest materials into dust, but not in this manner to render the road more solid than before; to attain which end, the gravel must be left on the road-way, to be moved laterally by carriage-wheels, to be pushed forwards, thrust backwards, and beaten down in detail by horse-shoes, until every angular stone becomes immovably fixed in a place suitable to it; by such gradual process, and not otherwise, the road becomes in due time a smooth mass of consolidated stone.

But a practical mistake, by which this crushing of materials was aggravated, resulted from misdirected legislation for the protection of turnpike-roads. Its advocates certainly did not intend alleviation

of toll in favour of broad wheels unless they were truly cylindrical; but this condition presents so many obstacles in practice,* however excellent in theory, that the established dished wheel continues in general use; although the dished wheel, being a sectional portion of a cone (not of a cylinder), cannot roll in a strait line if the felly is broad and flat on the sole, as the law directs; therefore the middle of the felly has always been made prominent, and the entire load is carried on the middle tire. Thus the surface of the road does not profit by the apparent breadth of the wheel, while the precise conditions of the promised alleviation of toll are still gravely repeated in every successive Act of Parliament on the subject,† although non-

* Such wheels limit the breadth of the load above; they are awkward in turning; and do not possess the advantage resulting from the outward slope of the upper part of the felly of a dished wheel, whereby, in mutual collision with another carriage, the conflicting wheels yield gradually, and prevent any violent shock of the naves thus protected. Dished wheels also possess a greater strength of construction; for the felly being compressible, owing to the slant of the spokes which support it, is strained tight by the contraction of the iron-tire in cooling, and being thereby kept always in a state of tension is not liable to become loose in the joints; and these wheels are capable of resisting lateral shocks upon a rough roadway. A wheel falling into a cavity or rut receives from the sloping load not only an extra pressure but also a lateral thrust, the tendency of which is to force the nave outwards through the felly; but the nave of a dished wheel resembles the crown of an arch bearing upon the felly as a base, which cannot be extended, because, being of a circular figure, it admits of no extension while entire—thus the felly is equivalent to the abutments of this arch, or rather to the tie beam of a trussed frame. The only upright wheels which have been at all successful contain the above principle in their construction; they are of iron, and each of them resembles a pair of dished wheels set face to face; but even these are not now (as at first) made perfectly upright or cylindrical.

† The General Turnpike Act now in force, 3° Geo. IV. c. 126 (A. D. 1822), thus carefully expresses the legislative definition of cylindrical wheels, as if then or previously in use. Section IX. ' Provided such cart, waggon or other such carriage, shall have the soles

compliance therewith has always been notorious; the road therefore suffers by the extra-weights allowed to be carried on broad wheels, as well as from subtraction of tolls; the carrier suffers from using wheels which add a ton to the weight of the carriage, and render necessary an additional horse; and eventually the public suffers from both these causes, produced by a strange medley of erroneous legislation, and bad practice arising from the customary violation of its rules; yet the infliction has already endured throughout more than half a century, and the remote posterity of its authors may still perhaps witness the stately instruments of destruction in the form of broad-wheeled stage waggons, laden with eight tons, slowly crushing road-repair materials, dearly purchased and usually far-fetched.

Efforts have not been wanting to enlighten the public as to the non-existence of cylindrical wheels, and the injurious tendency of conical wheels, 'flat on the sole,' were it possible to drag them along a road. In the year 1796 a Select Committee of the House of Commons collected evidence, and reported, 'That the roads suffered materially

'or bottoms of the fellies of all the wheels thereof rolling on a flat surface, and the nails 'of the tire of such wheels countersunk, and be cylindrical; that is to say, of the same 'diameter on the inside next the carriage as on the outside, so that when such wheels shall 'be rolling on a flat or level surface, the whole breadth thereof shall bear equally on such 'flat or level surface; and provided that the opposite ends of the axletrees of such 'waggon, cart or other carriage, so far as the same shall be inserted in the respective 'naves of the wheels thereof, shall be horizontal and in the continuance of one strait 'line, without forming any angle with each other; and so that in each pair of wheels 'belonging to such carriage, the lower parts, when resting on the ground, shall be at 'the same distance from each other as the upper parts of such pair of wheels.'

'from the form of the sixteen-inch wheels, and from the projecting tire 'and improper form of the nine-inch wheels (then and ever since) in 'use;' and in the years 1806 to 1811, successive Committees of the House of Commons investigated the entire subject, explaining and vituperating most distinctly the folly of favouring wheels as cylindrical which were in fact conical; but all in vain, as we have already seen.

On the other hand, a considerable benefit has resulted from the general introduction of Springs, concerning which, as they regard ease of draft, Mr. Edgeworth published an essay in the year 1788, concluding that they generally saved one horse in four, which in fact may be deemed a fair average; and in the year 1806, Mr. Davies Gilbert communicated to the Committee on Highways a valuable paper, in which he says, 'Springs were in all likelihood first applied to carriages 'with no other view than for the ease of the traveller; they have since 'been found to answer several important ends. They convert all percussions into mere increase of pressure, thus preserving both the carriage and the road materials from the effect of blows; and small 'obstacles are surmounted, when the springs allow the frame and 'wheels freely to ascend, without sensibly moving the body of the 'carriage from its direct course.'

Another element of facility in draft may be beneficially adopted by the introduction of two-wheeled instead of four-wheeled vehicles, which last increase the friction with the number of wheels; to the avoidance of which extra-friction we may approximate, where four

wheels are necessary, by imposing the greatest possible portion of the weight on the hind wheels, leaving the fore wheels nearly idle; but where two wheels instead of four can be safely and conveniently adopted, we may conclude, from experiments and inferences not hastily made, that a two-wheeled cart with springs, requires no more than half the tractive power required to move the same weight placed on four wheels without springs.

Mr. Telford commenced his practice in solid road-making between Glasgow and Carlisle; and in the vicinity of the former place, no material for covering the road exists, nor consequently had ever been used, except hammer-broken rock, which, under the name of *metalling*, has since been introduced into England, chiefly by Mr. M'Adam, and is a most useful novelty: the requisite foundation of such metalling may be learned in the several specifications which appear in the Appendix to this volume, as Mr. Telford always provided for it by stony masses, laid in the most compact manner by hand. A book was published at that time, recommending in preference a substratum of vegetable earth, or even elastic bog, for any line of road*, which was in effect to create a perpetually uphill draft; but this opinion, after finding admirers among the lovers of novelty and wonder, is almost forgotten; and the advantage of a solid foundation (even more solid than that of Mr. Telford's Glasgow and Holyhead Roads) has since

* This doctrine is asserted at some length by Mr. M'Adam, in his Evidence before a Select Committee of the House of Commons on Highways.—See their Second Report, 25 June 1819, pp. 23, 24.

been proved by the INDICATOR of Mr. Macneill, which shows the state of any road, and of every part of a road, by simply driving over it; that is, by measuring the quantity of resistance opposed to every footstep of the horse moving at a uniform rate.

A further improvement in road-making is likely to arise from experiments which originated under the auspices of Mr. Telford on the Holyhead Road, near Wolverhampton; it consists in the possibility of increasing the durability of ordinary road-metalling, by admixture of a moderate quantity of impenetrable materials; and this novelty is now secure of a decisive trial.

Mr. Telford's disapprobation of Railroads may perhaps be inferred too strongly from his objection to that which was first proposed between Birmingham and Liverpool in the year 1825 (see page 86 of this volume), so that some explanation is necessary on the subject. Mr. Telford's objection against railroads was not directed against the utility of a rapid conveyance of travellers; but merely against them as a rival conveyance of heavy goods usually carried on canals; and in this he has been fully justified by experience. The original prospectus of the Liverpool and Manchester Railroad estimated the expected profits of the Company to arise from the daily carriage of 3,850 tons weight in heavy articles, and 100 tons weight only from the conveyance of passengers; whereas the result has been, that in the year 1833 the gross profit arising from the carriage of goods and Irish cattle amounted to £.22,057; from the conveyance of passengers, to £.51,897. Mr. Tel-

ford often expressed an opinion that the wear of engines and rails would be so considerable, that the expense of carrying coals and heavy merchandize must be greater on railroads than on canals, and he used to instance the Shropshire Canal, on which one horse frequently draws twenty boats, each laden with seven tons of coals, the average number of such boats being twelve, laden with 84 tons. Previously to Mr. Telford's death, it never was contemplated to construct extensive lines of railroads, for the sole purpose of carrying passengers; heretofore (as already stated) it was presumed and calculated that large quantities of goods would also be carried; whereas it is now generally admitted that goods which do not require very speedy conveyance for special purposes cannot be profitably carried on the railroads which have adopted a rapid locomotive power.

So far was Mr. Telford from being adverse to railways generally, that he surveyed and reported upon many intended lines on which coals and other heavy materials were to be conveyed by horse power; for instance, he reported on the intended Newcastle-on-Tyne and Carlisle Railway, when a difference of opinion as to the most eligible line was referred to him: he surveyed and reported on a proposed line between Glasgow and Newcastle-on-Tyne, by way of Berwick; and the Stratford and Morton Railway was constructed under his direction.

Mr. Telford's experiments on the strength of iron wire are in high estimation, and the result of them is inserted in the Appendix (O. 4.); and not long before his death, he instituted a series of experiments in

the Adelaide Gallery on the resistance of canal boats, drawn at various rates of velocity; this subject has since been carefully prosecuted by Mr. Macneill, in a series of experiments made upon the Forth and Clyde, the Monkland and the Paisley Canals, of which the results are published in the first volume of the Transactions of the Society of Civil Engineers.

The infrequency of such experiments undertaken with general views has already been noticed in this preface, and it is among the best prospects of the Institution of Civil Engineers, that it insures publicity and favourable attention to every man of modesty and merit who shall appropriate his time to patient observation, or judicious experiments for the improvement of knowledge in any of the multifarious objects pertinent to the profession; and Mr. Telford's bequest enables that Society to reward all such recorded labours in an appropriate manner.

Mr. Telford's Pocket Memorandum Book, which will be found carefully digested in the valuable Appendix (Y. 1.) sufficiently exemplifies the uncertainty, and occasionally the conflicting results recorded by those authors on whom Civil Engineers mainly rely; and amply proves, by its defective character, that we are surrounded by objects of all grades, which call for research:—the average evaporation of water surface exposed freely to the influences of the atmosphere (Leakage precluded, or the amount of it ascertained) is not known within a reasonable approximation;—the effect of vibration and oscillation opens a large field for acute investigation;—and the direction of river cur-

rents and receding tides, as well as the movement of sand and shingle on or near the coast, from the effect of winds and waves, might perhaps be so closely observed and so well elucidated, as to become in some degree subjected to human guidance.

J. R.

April 1838.

DESCRIPTIVE NARRATIVE

OF

THE WORKS OF THOMAS TELFORD.

HAVING for more than half a century been constantly employed in planning and conducting works of greater variety and magnitude than fall to the share of most men of my profession, I feel it as a duty incumbent on me to bequeath to posterity a connected description of these operations; for although they have been from time to time recorded in Reports to Parliament, to public bodies, and joint-stock companies, yet this having been done occasionally during a long series of years, it now becomes necessary, in order to render my experience generally useful, that a careful selection be made from the formidable mass which has unavoidably accumulated, so as to afford details of practical operations; thus composing a work, partly historical and partly descriptive, illustrated with numerous drawings and plans, wherever such assistance appears to be necessary or useful.

The several works might be classed under Civil Architecture, Bridge Building, Road Making, Inland Navigation, Drainage, the construction of Docks, and the improvement of Harbours; but as the increase of my own knowledge has been measured by the progress of these works in the order of time, I am persuaded it will be more instructive to others, as well as easier to myself, to write personally, if not as an

annalist, always insisting largely on the earliest instances of every improved operation, and therein not omitting to develop the origin of further views, and to describe the accession of further improvements to the present time.

The early part of my life was spent in employment as a mason, chiefly in my native district of Eskdale,* a mountainous tract of the County of Dumfries, being the western march of the Scottish Border, which being pastoral is but thinly peopled, and where masonry operations consist chiefly in building dwelling-houses for the farmers, with the necessary appendages, varied only as the farm is pastoral or arable. Wherever regular roads were substituted for the old horse tracks, and wheel carriages introduced, bridges, numerous but small, were to be built over the mountain streams; those, however, furnished considerable employment to the practical mason, and I thus became early experienced in the requisite considerations and details. In this district land-owners' dwellings occasionally occur; but the greater portion of the country being the property of the Buccleuch family, farm-houses are more usual, and, to the credit of that wealthy and excellent family, their tenantry reside in good habitations, and are in no want of the comforts of life. The parish churches are plain and simple, and the Manses of the ministers differ little from the best kind of farm-houses.

In all these convenience and usefulness only are studied, yet peculiar advantages are thus afforded to the young practitioner; for as there is not sufficient employment to produce a division of labour in building, he is under the necessity of making himself acquainted with every detail in procuring, preparing and employing every kind of material, whether it be the produce of the forest, the quarry, or the forge, and this necessity, although unfavourable to the dexterity of the individual

workman, who earns his livelihood by expertness in one operation, is of singular advantage to the future architect or engineer, whose professional excellence must rest on the adaptation of materials and a confirmed habit of discrimination and judicious superintendence.

My Readers may not dissent from these observations; but few of them, unless practical men, will feel their full force. Youths of respectability and competent education, who contemplate Civil Engineering as a profession, are seldom aware how far they ought to descend in order to found the basis of future elevation. Not only are the natural senses of seeing and feeling requisite in the examination of materials, but also the practised eye, and the hand which has experience of the kind and qualities of stone, of lime, of iron, of timber, and even of earth, and of the effects of human ingenuity in applying and combining all these substances,—is necessary for arriving at mastery in the profession: for how can a man give judicious directions unless he possesses personal knowledge of the details requisite to effect his ultimate purpose in the best and cheapest manner? It has happened to me more than once, when taking opportunities of being useful to a young man of merit, that I have experienced opposition in taking him from his books and drawings, and placing a mallet, chisel or trowel in his hand, till, rendered confident by the solid knowledge which experience only can bestow, he was qualified to insist on the due performance of workmanship, and to judge of merit in the lower as well as the higher departments of a profession in which no kind or degree of practical knowledge is superfluous. For this reason I ever congratulate myself upon the circumstances which compelled me to begin by working with my own hands, and thus to acquire early experience of the habits and feelings of workmen; it being equally important to the Civil Engineer, as to Naval or Military Commanders, to have passed through all the grades of their profession.

It was only in the latter part of the last century that the western border or march between North and South Britain was rendered productive or valuable by a regular system of improvements, when the good Duke Henry of Buccleuch, the kind father of his tenantry and the benefactor of the district, within my memory caused it to be intersected by roads, and assisted in the improvements of the farm-houses upon his extensive property. Until then most of them consisted of one story of mud walls or rubble stones bedded in clay, and thatched with straw, rushes or heather, the floors being of earth, and the fire in the middle, having a plastered creel chimney for the escape of the smoke, and, instead of windows, small openings in the thick mud walls admitted a scanty light; in such hovels the peasantry usually dwelt within my memory, and examples still exist. Encouragement was afforded by paying the prime cost of the timber, slates and lime, the tenant performing the carriage and paying for the workmanship; and such expenses being considered at the end of the lease, he was thus enabled to effect desirable improvements, without employing too much of his own capital.

Under this judicious management the mud hovels have disappeared, having been replaced by comfortable dwelling-houses, with convenient offices, the walls of stone and lime-mortar, slated roofs, masonry chimneys and boarded floors; the plan having been furnished by the Duke's surveyor, the building was erected under his inspection, and the lower parts of Eskdale abounding with sandstone, limestone and coal, most of the materials were readily procured; and although in the upper parts of the country argillaceous schistus (not a very durable material) predominated, yet, being conveniently situated and easily quarried, it is generally employed for the bulk of the fabric, with sandstone dressings for the doors, windows, tabling and skews of the roof. With regard

to timber, although the lower part of the valley of the Esk produces much fine oak, ash and pine, yet the Duke preferred purchasing Baltic timber, which was landed on the shore of the Solway Firth (as was the excellent slate of North Wales), and carted into the interior by the tenantry.

The market towns near the border having been formerly exposed to frequent and destructive inroads, Langholm, the principal and indeed the only town in Eskdale, partook of the poverty and meanness of those in the adjacent district; the Tolbooth only had any thing peculiar, being partly a prison and partly a justice hall, built with stone and lime-mortar, with an outside stair for ascent: a sort of bell tower, which of late years has been furnished with a clock, occupied the middle of the edifice, and its narrow iron-grated windows and the vault-like entrances gave it a gloomy gaol-like appearance; but within the last half century town improvement has more than kept pace with that of the surrounding country; comfort, convenience, and even a degree of elegance now prevails in private dwellings; and the Tolbooth is, in some places, decorated from Greek and Roman examples. But in thus tracing the progress of architecture in the wild and formerly distracted western marches, I am bound to say that no such barbarous state of the art is applicable to the eastern side of the Island; the Abbeys of Kelso, Melrose, Dryburgh and Jedburgh having been built in the best style of ecclesiastical architecture under David I., who died in the year 1155.

The castles of the ancient warlike chieftains of the Scottish Border, "although not comparable with the Baronial residences of English families, of much less power and influence," were yet of considerable magnitude, the construction rude, and the walls of great thickness and

strength, even in the wildest parts of the western marches, as at the top of Liddesdale, where the ruins of Hermitage Castle exhibit no contemptible specimen: it is described by Scott in his Border Antiquities as "A huge building, about 100 feet square; the walls are entire, but the inside totally ruined; the plan is singular, the east and west fronts of the square being flat, and without any projection, whereas the northern and southern sides present a curtain, flanked by a large tower at each end. The main entrance seems to have been from the west by a very high portal arch, which ascends to the projecting battlements in the top of the castle, but this arch enters only a little way at this extraordinary height, being blocked by an inner wall, through which an entrance of moderate dimensions leads into the castle court. above the interior portal are holes, (machicolations,) for pouring down stones, arrows and other offensive weapons." The name of this castle was derived from an ancient hermit's cell; it is said to have been built by Alexander II. in 1240.

Hermitage Castle.

The same author states, "That the smaller gentlemen, whether the heads or branches of clans or of distinct families, inhabited dwellings upon a still smaller scale, called Peels or Bastle Houses; these were surrounded by an enclosure or barmkin, the wall whereof was, according to the statute, a yard thick, and six yards in height, surrounding at least a space of sixty feet square. Within this space the laird built his tower, with its projecting battlements, and usually secured the entrance by two doors, the first of grated iron, the innermost, oak with clenched nails; the apartments were placed directly over each other, accessible only by a narrow turnpike stair, easily blocked up and defended."

The following description of Closeburn Castle, situated about twelve miles above Dumfries, built in the 12th century, and belonging to Roger de Kirkpatrick, a follower of Robert Bruce, is a fair specimen of the border towers. It is quadrilateral, all vaulted; the lower apartment is under the level of the ground; the wall is twelve feet thick; the door is in a circular arch, with zig-zag mouldings cut in hard granite; the only communication with the hall is by a trap door. The second floor originally consisted of a hall, the approach to the door of which was by a ladder, which was readily taken up; the old iron door is still remaining. This hall was probably the dining-room, guard chamber, and dormitory of the garrison; when invested by an enemy, a small turnpike stair, built in the wall, ascended to the principal apartments of the governor of the castle; the fire was made in the middle of the floor, as there was only one stack of chimneys, and those in the centre of the building; above this hall there were two series of chambers, which are divided by oaken floors, and, above these, an arched roof crowned the building; a way, fenced with a parapet, goes round the top; the dimensions of the building are forty-five feet six inches from

east to west, and thirty-three feet six inches from north to south; its height to the battlement forty-seven feet.

Sir Walter (then Mr.) Scott has thus described the usual mode of attack of the border tower: "Artillery being set out of the question, the attack was by bows and hagbuts, the discharging of which drove the defenders from the loop-holes and battlements, while the assailants heaping together quantities of wet straw, and setting it on fire, drove the garrison from story to story by means of smoke, and sometimes compelled them to surrender.

"The mode of defence, by stones, arrows, scalding water, &c. was equally obvious; and in ordinary cases, by such means of resistance and the military disposition of the inhabitants in the neighbourhood, 'who readily rose to the fray,' a desultory attack was repulsed."

Of the greater castles, there were several in the western marches of still greater importance than Hermitage; as the castles of Lochmaben, built by Robert Bruce, lord of Annandale, and afterwards King of Scotland; it stands upon a peninsula in the loch. The original castle occupies about an acre of ground, and contains three courts, strongly built with stone and lime; the walls twelve feet thick; it was surrounded by three deep ditches, filled with water from the loch; the whole fortification thus contained thirteen acres; the main ditch went through the castle, within which was a basin for holding the garrison boats out of the reach of the enemy. The principal entrance seems to have been by water.

There was also Carlaverock Castle, situated about nine miles south of Dumfries, on the north shore of the Solway Firth, between the con-

fluence of the rivers Nith and Lochar; it was the chief seat of the Maxwells, in the days of Malcolm Canmore.

Carlaverock Castle

This castle was of such importance as to require a regular attack by Edward I., with a numerous and well-appointed army, in the year 1300. Walter of Exeter gives a very particular description of the castle, and of the great crown vassals and their retainers; he also gives a detailed account of the operations of the siege. This document was written originally in Norman French, and translated by Nicholas Harris Nicholas; the original is preserved in the British Museum. The whole being too long for a work of this nature, I shall only insert what more immediately relates to the castle. He says, "Carlaverock was a castle so strong that it did not fear a siege; therefore the king came himself, because it would not consent to surrender, as it was always furnished for its defence with men, engines and provisions. Its shape was in the form of a shield, for it had three sides, with a tower at each angle; but one was a double one, so high and so large, that under it was a gate

with a draw-bridge, and other defences; it had good walls and good ditches, filled eye-deep with water, and I believe there never was seen a castle so beautifully situated; for at once might be seen the Irish Sea to the west, and to the north a fine country, surrounded by an arm of the sea; so that no creature born could approach it on two sides without putting himself in danger of the sea.

"Towards the south it was also difficult; there were numerous defiles of wood, marshes and ditches, and the river washed it; it was therefore necessary for the host to approach from the east, where the hill slopes. In that place, by the king's command, his battalia were formed into three, as they best could be quartered; then were the banners displayed, where one might observe many a warrior exercising his horse, and there appeared three thousand gallant men at arms; then might be seen gold and silver, and the noblest and best of rich colours, so as to render brilliant the entire valley; consequently those of the castle, on seeing us arrive, as I believe, deemed that they were in greater peril than they could before remember. Soon afterwards it fortunately happened that the navy arrived with the engines and provisions, and then the footmen began to march against the castle; then might be seen stones, arrows, and quarrels from the cross-bows, to fly amongst them; but so effectually did those within exchange their tokens with those without, that in one short hour there were many persons wounded and maimed, and I know not how many killed."

After describing very particularly the different chiefs and their coat armour, he goes on to say, "Those within continually relieved one another; for always as one became fatigued, another returned fresh and stout; and notwithstanding such assaults were made upon them, they would not surrender; but so defended themselves, that they resisted

those who attacked all that day and night, and the next day till tierce (nine in the morning); but their courage was considerably depressed during the attack by brother Robert,* who sent numerous stones from the Robinet without cessation, from the dawn of the preceding day until the evening; moreover, on the other side, he was erecting three other engines, very large and of great power, and very destructive, which cast down and cleave whatever they strike, fortified town, citadel or barrier; nothing is safe from their strokes; yet those within did not flinch until some of them were slain; but the pieces flew in such a manner wherever the stones entered, that when they struck any of the garrison, neither iron cap nor wooden target could save him from a wound.

"And when they saw that they could not hold out any longer, the garrison begged for peace, and put out a pennon; but he that displayed it, was shot with an arrow through the hand into the face; then he begged that they would shoot no more at him, for they would give up the castle to the king, and throw themselves upon his mercy; and the marshal and constable, who always remained upon the spot, at that notice forbad the assault, and those within surrendered the castle to them.

"The besieged, who had thus retarded the progress of this mighty host, now passed in review before King Edward, and, including all ranks, were found to amount to no more than sixty men, who were beheld with astonishment.

* Frère Robert (Brother Robert), meaning that he was a monk, whose studies had probably enabled him to imitate the ancient catapulta, with enough of originality or adaptation to call his engine after his own name, a "Robinet." The Jewish historian, Josephus, gives an instance of a man's head being knocked off at a distance of three stadia, 660 English yards, by a Roman catapult, at the siege of Jotapata.

"As soon as the castle fell into Edward's hands, he caused his banner, and that of St. George and St. Edward, to be displayed on its battlements, to which were also added the banner of Sir John Segrave, the marshal, and of the Earl of Hereford, the constable of the army, together with that of Lord Clifford, who was appointed governor. Edward was at Carlaverock on the 12th of July 1300."

Though the life of the borderers was rude and precarious, and to us apparently uncomfortable, yet, from having their utmost energies called forth, they became renowned in desultory warfare; and from early habits they no doubt felt a species of enjoyment in the adventures, offensive and defensive, in which they were constantly engaged.

Malcolm, surnamed Canmore or Great Head, who began to reign in 1056, was the son of Duncan, slain by Macbeth, and immortalized by Shakspeare; he had benefited by exile in England, and afterwards by his marriage with the amiable and beautiful Saxon Princess Margaret, who, with her brother, Edgar Atheling, took refuge in Scotland, to avoid the fury of William the Conqueror, the cause of many other Saxons of condition settling in that Kingdom.

During the violent contests which took place in England while Scotland was governed by wiser Princes, for upwards of a century, not a few Norman Barons found it advisable to accept an asylum offered by the Sovereigns of that nation, who had the good sense to employ these better instructed strangers, thus introducing a degree of civilization amongst their own rude and turbulent subjects. Malcolm Canmore received Patrick, Earl of Northumberland (called Gospatrick or Corspatrick), and gave him the castle of Dunbar; he was afterwards created Earl of Dunbar and March; and most of the principal families in Scotland are

descended from Norman or Saxon exiles, seeking refuge from the oppression of the inexorable conqueror, who, according to the English historians, at that period (1069), carried fire and sword from York to Durham, and from the Tees to the Tyne, rendering the whole a scene of desolation, not worth recording as property in the Domesday book.

David I. son of Malcolm Canmore, who had been bred at the court of his brother-in-law, Henry I., surnamed Beauclerk, was one of the ablest and best sovereigns of his time. I have already enumerated the religious houses established by him on the Eastern Scottish Border; and as castle building had ever since the Norman conquest been extensively practised in England, it is more than probable that the great fortresses and castellated dwellings, as well as the before-mentioned monastic edifices, were built under the direction of the naturalized exiles. On the English border, the New-castle upon Tyne and the castle at Carlisle were built between the years 1080 and 1092.

While friendly intercourse between the two Kingdoms continued, the introduction of foreigners, and the before-mentioned religious establishments, promised to change the habits of the borderers; but another century of adverse occurrences checked the progress of improvements, and the violent interference of the crafty, able and ambitious Edward I., totally destroyed all the good that had been accomplished; for although his project of subjugation was eventually unsuccessful, Scotland was left torn by factions, and the great fortresses had been destroyed, not only by the enemy, but by the Scots themselves, who discovered that it was more advisable to contend with the enemy in the open country, than depend upon the great masonry strengths which they themselves could not effectually defend, nor reconquer when taken by the enemy.

From the time of Robert Bruce, therefore, the border military architecture of the Scots was confined to the small square towers or castellated houses, calculated to withstand only desultory attacks, and from which the enterprising chieftain and his associates issued to make similar forays upon his enemies on the English side of the river, or ideal border boundary.

But I begin to perceive I am running into prolixity on border details, pardonably, I hope, in an old man, speaking of the scenes of his youth, since immortalized in verse and prose by a more illustrious borderer, Sir Walter Scott. I ever recollect with pride and pleasure my native parish of Westerkirk, where I was born, on the banks of the Esk, in the year 1757, and where also were born that eminent brotherhood of the Malcolm family, four of whom have risen to high rank, and the honour of knighthood, in the service of their country; of whom two have been made Grand Crosses, and one a Knight Commander of the Order of the Bath. I was for some years a school-fellow of the elder brothers of that distinguished family. Colonel Pasley has since emerged from the same neighbourhood; it was left for him first to demonstrate the folly of squandering the reputation of the English army in desultory expeditions. The failures at the Helder, at Quiberon, at Ferrol, even at Walcheren, had occurred in vain, when Pasley employed his classical pen in convincing the public of the wisdom of enabling the Great Captain to fight the French in successive campaigns; supplies of men and of money were no longer stinted by imprudent parsimony, and the Peninsular War terminated in the southern provinces of France. Nor ought I to omit that Colonel Pasley has applied the test of experiment to the pressure of earth, and other materials, and by thus rectifying the unfounded theories heretofore prevalent,

has rendered essential service to the Civil as well as the Military Engineer *.

At the age of 23 I considered myself to be master of my art, as practised in the county of Dumfries; and having then had an opportunity of visiting Edinburgh, I now dismiss my border anecdotes, and pass to scenes of more public interest and importance.

In our northern metropolis the art of delineating architecture upon paper, had long been practised; and in that ancient British city, a short time before I visited it (1780), commenced the splendid improvements which have since been extended in every direction: this opened to me a new and extensive field for observation, where architecture is appropriated to the purposes of magnificence, as well as utility.

Edinburgh was first known by the appellation of the Maiden Castle, from its having been the residence of the daughters of the Pictish Kings, until they were married; but since it was conquered by Edwin, the Saxon Prince of Northumberland, in 617, it has borne the name of Edwin's Burgh.

The grandeur of its general situation is perhaps unrivalled, and is best seen from the walks which now encompass the Calton Hill, the view comprising a great extent of fertile and well-cultivated country, a large city of romantic appearance, one-half consisting of very regular

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* Mr. Telford always extolled the value of Colonel Pasley's scientific works, as being founded on personal investigation of facts, and authentic beyond example. He particularly approved of the Colonel's "Observations on the expediency and practicability of simplifying and improving Measures, Weights and Money," which, though not published till after Mr. Telford's death, had been submitted to him by the author, as lithographed for private circulation.

stone buildings, which have sprung up within the memory of man, the other half forming the old city of Edinburgh; at one extremity terminated by the Castle of ancient and modern features, placed on an abrupt eminence, while at the bottom of the rocky ridge, occupied by the High-street of the old town, is seen the Royal Palace of Holyrood, the port, and well-frequented roadstead of Leith, with the broad River Forth immediately northward, and in the remote distance the Grampian range of mountains, defining the Highlands; towards the east an extensive sea view; and southward (disjoined from the Calton Hill by an abrupt valley) the Salisbury Craig, surmounted by Arthur's Seat, an uninhabited counterpart of the site of the High-street and Castle of Edinburgh, and like that ascending from Holyrood-House.

In the northern metropolis I found practical illustrations of various styles of architecture in the rude features of the ancient Pictish Castle, and in the lofty tower-like dwellings, crowded along a narrow ridge under the protection of the Castle; slight attempts at Roman architecture in 1660 by Inigo Jones, in Heriot's Hospital; and that style more distinctly developed by Sir W. Bruce, in rebuilding Holyrood Palace after the restoration of Charles II. In the ruins of its once magnificent chapel I found varieties of Gothic architecture, from the plain Norman circular intersecting arches to the highly pointed style; for although founded in 1128, yet the western entrance, and the other parts, denote the style prevalent in the fourteenth century; that is to say, on the outside flying buttresses, with canopied niches and highly pointed arches upon clustered columns in the interior, thus exhibiting successive improvements.

Having acquired a general knowledge of drawing, and particularly of its application to architecture, and having studied all that was to be

seen in Edinburgh, in returning to the western border, I visited the justly celebrated Abbey of Melrose. This Abbey, originally founded by David I. in 1136, underwent a total change in the middle of the fourteenth century, so that the present ruins of architecture and sculpture are of the most delicate and perfect workmanship: here are none of the Norman features, like those of the other border abbeys of Kelso and Jedburgh, where both plain and ornamental circular arches predominate, and the well-known zig-zag mouldings; whereas at Melrose the style is that of the time of Edward II.: this monarch, in a plundering expedition, A.D. 1322, destroyed the old abbey, slew the monks of Melrose and Dryburgh, and carried off the consecrated plate. Robert Bruce, the Scottish King, harassed his retreat as far as York, and with the plunder of the northern counties of England rebuilt Melrose Abbey, in the best manner of the age, when the most perfect Gothic had been fully established both in England and France.*

Conformably to this, the arches at Melrose are highly pointed, the windows formed into rich tracery; flying buttresses, with canopied niches and panneled pinnacles, are introduced, and ogee mouldings over the principal doors and windows: this fine specimen of ornamented

* Nothing is more difficult than to assign dates to ancient ecclesiastical buildings, successive Bishops or Lord Abbots emulating each other in additions and improvements, mostly ornamental. Thus the cathedral of Winchester, built in all its vastness by Bishop Walkelin, a kinsman and chaplain to the Norman Conqueror, was renovated and metamorphosed into the pointed style by William of Wykeham, towards the end of the 14th century, by clustering the columns, rebuilding the upper half of the arches, and covering the nave with a groined ceiling, at a greater expense apparently than was incurred by Walkelin, the founder, whose north and south transepts still remain plain and massive, with semicircular arches. With this explanation, which is applicable in some degree to all English cathedrals, except Salisbury, I subjoin dates of the commencement of the following:—Winchester, 1073; Durham, 1093; Lincoln, 1123; Peterborough, 1160; Salisbury, 1217; Worcester, 1218; York, 1227; Lichfield, 1295. In France: the cathedral of Rheims, 1020; Clugny, 1093; St. Dennis, 1140; Amiens, 1220.

Gothic is of considerable dimensions; it is in the form of St. John's cross; the length 258 feet, breadth 137 feet, the height of the south window 34 feet, the breadth 15; the east window is 24 feet high, the breadth 16 feet; under it was the great altar: this window consists of four tall mullions, with fine tracery; on each side are niches for statues, and around the edifice sixty-eight similar niches yet remain: the tower is at the intersection of the cross, its height being 75 feet.

In magnitude this edifice will not bear a comparison with the first class of magnificent English cathedrals; but in regard to elegance of design, or perfection of workmanship, it is not inferior to any in the most perfect era of Gothic architecture.

About six miles south of Edinburgh, Roslyn Chapel is a highly ornamented Gothic edifice, built about the middle of the fifteenth century, by William of St. Clair, Earl of Caithness and Orkney, and Duke of Oldenburg, who is said to have collected the best workmen from all parts, and to have rewarded them with princely munificence. They have done him justice in making his chapel the admiration of ages. Tradition says the plan was drawn at Rome.

The ancestor of this family was a companion of William the Conqueror, and, having taken refuge in Scotland, obtained from Malcolm Canmore a grant of the Barony of Roslyn. James the Second of Scotland appointed one of the family Grand Master of the fraternity of Freemasons, which accounts for the construction of this masterpiece of art. The length of the chapel is 68 feet, its breadth 34 feet, and the height from the floor to the top of the arched roof 40 feet; it is surrounded at a little distance by a stone wall, with one entrance on the north side; at the east corner there is a descent by twenty steps into a crypt or

chapel, partly subterraneous, supposed to have been used as a sacristy and vestry; the length of this apartment is 36 feet, breadth 14 feet, and height 15 feet; in this chapel are the monuments of the Earls of Caithness.

In the year 1782, after having acquired the rudiments of my profession, I considered that my native country afforded few opportunities of exercising it to any extent, and therefore judged it advisable (like many of my countrymen) to proceed southward, where industry might find more employment, and be better rewarded.

With these views, I made my way direct to London, as the great mart for talents and ingenuity; and I was fortunate in getting employed at the quadrangle of Somerset-place buildings, where I acquired much practical information, both in the useful and ornamental branches of architecture; and in the course of my two years' residence in London, I had an opportunity of examining the numerous public buildings of the metropolis of Great Britain, and I became known to Sir W. Chambers and Mr. Robert Adam, the two most distinguished architects of that day; the former haughty and reserved, the latter affable and communicative; and a similar distinction of character pervaded their works, Sir William's being stiff and formal, those of Mr. Adam playful and gay; and although from neither did I derive any direct advantage, yet so powerful is manner, that the latter left the most favourable impression, while the interviews with both convinced me that my safest plan was to endeavour to advance, if by slower degrees, yet by independent conduct.

The next step in my professional career was the superintendence of a house ordered to be built in Portsmouth Dock-yard, for the resident Commissioner; it was of considerable magnitude (as in contemplation of future visits of the King), and involved some degree of responsibility.

This house was designed by Samuel Wyat, one of a numerous family of architects; he also built it by contract, and my superintendence afforded me experience in house-building of a higher class and on a greater scale than previously had been entrusted to me. [*See* Plate, No. 2.]

During the three years that I attended the building of the Commissioner's house, and of a new chapel for the Dock-yard, I had an opportunity of observing the various operations necessary in the foundations and construction of graving docks, wharf-walls, and similar works, which afterwards became my chief occupation.

This great naval arsenal, combining all the conveniences which wealth can provide for the creation and maintenance of numerous fleets, exemplified the extent to which ingenuity can be carried; and, in the several departments, the regularity and despatch with which the various stores are thereby received and issued.

This great establishment being on the land side protected by a very regular and extensive line of fortification, then in progress, exhibited also a very interesting specimen of under-ground defences and military architecture on the largest scale.

The Dock-yard works at Portsmouth under my superintendence having been completed in 1787, the late Sir William Pulteney (who was originally a border Johnstone, of the family of Westerhall in my native parish, and who, at that time represented the town of Shrewsbury in Parliament,) invited me into Shropshire, to superintend some alterations in Shrewsbury Castle, which he wished to fit up as a temporary residence.

This castle was originally built as the baronial residence of Roger de Montgomery, a relation of William the Conqueror, who bestowed

a very extensive district upon him, in order that he might, in conjunction with Hugh Lupus (fixed at Chester) keep in subjection the inhabitants of North Wales: this they not only performed, but took possession of all the adjacent fertile country. Earl Roger also built the Castles of Ludlow and Bridgenorth, and the extensive Monasteries of Wenlock and Shrewsbury, and the Abbey of Buildwas.

After the fall of the great house of Montgomery, in the reign of Henry I., on the forfeiture of Robert de Belesme, the castle became the property of the Crown, and continued so till 1663, when it was bestowed by Charles II. upon Lord Newport, from whence it devolved on Pulteney Earl of Bath, and, through marriage with the heiress of that family, became the property of Sir William Pulteney.

The town of Shrewsbury is situated on a peninsula, encompassed by the River Severn, except a neck of land about 450 yards across, occupied by the castle and the town walls; it was therefore only through a gateway in these walls, immediately under the castle, or over the two bridges, also castellated, that the communications with the country were open; the river, fordable only in very dry weather, protecting all the other parts of the town; thus affording an example of the site of an ancient British city, selected for the residence of the princes of Powis-land, and as one of the keys of North Wales. It was further strengthened by the Saxon Earls of the Welsh marches, and rendered of still more importance when it became the residence of the greatest Norman Baron, "Comes Rogerius," relation and confidential friend of the most warlike prince in Europe.

This castle, in the course of successive ages of turbulence and contention, has undergone so many changes, that it is not possible to

determine its original form and dimensions. Fifty-one dwellings were destroyed by the Norman Baron for enlargement of its site; nor is it too much to conjecture that the castle in its perfect state included the space now occupied by the free-school and council-house; but of this extensive fortress, only the keep remains, consisting of two round towers of equal diameters, embattled and pierced, and connected by a square building, about 100 feet in length, with a small court on its eastern side; an arched gateway may have been a part of the original structure, its walls having sustained a tower for the portcullis: on the opposite side is a postern gate, under an embattled turret. 'From the beams of the roof and floors of the castle being enriched with carving, and from the position of a small stair in each end wall terminating at different heights, it is probable that the square space between the towers consisted of one apartment only on each floor. It will be evident that the small portion of the building I have described, would not afford much room for magnificence; and all that Sir W. Pulteney required was no more than an occasional residence. The position of Shrewsbury Castle, on the isthmus, is so chosen, that in the north-eastern round tower a person may see from one of the windows the River Severn; coming from the westward, and through the opposite window, the same river passing down to the eastward, after having surrounded the town. The outer walls are 9 feet in thickness, the inner walls towards the court are 4 feet. Upon the whole, from its commanding situation, adjacent to a large town, yet sufficiently retired, and connected with historical associations, this fragment of a Norman castle is now a desirable residence for a small family. One memorial of its importance still exists,—the Knights of the Shire are elected in the castle court.

About six miles below Shrewsbury, on the Newport property, is a relique of antiquity, six or seven centuries older than the Norman

castle. On the eastern bank of the Severn, at Wroxeter, is the Roman town Uriconium, called in the poems of Llyware Hên (a British prince and poet, driven from Kymry-land (Cumberland) to this place by the Saxons), Ddinlle Vekron, the City Vekron (Wrekin.) He was born in A. D. 502, and is said to have lived until he was 145 years old. In his time the Britons retired from this city, before the flames of the Saxon army, who called the place Wrekoncester, since by contraction Wroxeter.

The extent of the Roman town must have been nearly a mile across; its site is still distinguished by a blacker and richer soil of mould than the adjacent fields, and the stone foundations of ancient buildings, at no great depth under the surface of the ground, are manifest in long-continued drought; so that when the occupiers of the land need any stones for building, they mark the scorched parts, and after the harvest, dig out what suits their purpose. When I was at Shrewsbury, such a circumstance occurred, where a number of small pillars and a paved floor were discovered at about two feet under the surface of the ground; upon which the excavation was suspended until Sir William Pulteney gave permission to proceed. That being obtained, I caused the place to be carefully cleared to a considerable extent, and thus brought to light a set of Roman baths, of rude construction, but sufficiently perfect in regard to the several necessary apartments. Of these I made a correct plan, and sundry sections; and the Rev. Francis Leighton, of Shrewsbury, a person of antiquarian knowledge, having written a description of them, it was read before the "Society of Antiquaries" in London, on the 7th May 1789, and published in the 9th volume of the Archæologia. [*See* Plate 3, and Appendix (A.)] *

* It is necessary to say in this place, that the isometrical view of the Wroxeter baths (Plate 3) is explained on the plate itself, but not by the Appendix (A.), which refers to

I have given a plate of these baths, in order to shew the nature of such appendage to a Roman dwelling, in this provincial town. I have also given a plate of a small tesselated floor, or pavement, which about the same time was discovered a few miles to the south-west of Shrewsbury: this I also copied on the spot. [*See* Plate 4.]

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two plates (plan and section) inserted in the Archæologia; therefore, to connect Plate 3 with the Appendix (A.), a duplicate reference is added in the margin of the said Appendix.

But these documents afford little reason for designating the Roman remains at Wroxeter as baths. They are in reality *hypocaust* apartments (warmed by fire under the floor), in a tolerably good dwelling-house. The Romans having no chimneys (an invention not earlier than the middle of the fourteenth century), they could not defend themselves against cold, otherwise than by some contrivance which permitted smoke to escape, without entering the inhabited apartment. Their floors, therefore, were somewhat complex: on a strongly-paved foundation floor were placed many short pillars, round, if of stone, square, if of piled bricks. [Roman bricks (*lateres*) were in a flat form like our paving tiles.] Upon these pillars large paving tiles, adapted to the spaces between them, were so laid as to form a complete floor, upon which was next laid lime and mortar rubbish [*Rudus novum, aut vetus*] about a foot deep; and on the surface of that appears the visible floor of the room, adorned in the best apartments with patterns and figures of tesselated work [*tesseræ*, dimin. *tesselæ*, *tesserulæ*] of more delicacy, in proportion as their component particles were of small dimensions. Such hypocaust apartments could only be made on a ground-floor, so that there was no upper floor, except in crowded towns; and a tolerable country residence [villa] occupied, often inclosed, a great spot of ground. As to baths, no family of rank or even competence could fail to have one in a decent country residence; the use of woollen next the skin rendering frequent ablution necessary; and the remains of public baths in the Roman capital, prove that nothing was so sure a passport to popularity, as the enormously extensive baths in ancient Rome, built by the rivalry of successive emperors.

The Roman villa at Bignor, in Sussex, whether the residence of a mediatized British regulus or of a Roman prefect, has a bath apartment, with all its appendages, in good preservation. The only bath in these Wroxeter remains is the small warm bath apartment (marked B.), in which appears the stone beach, on which bathers used to sit as long as was necessary or agreeable.

The dimensions of the public Roman baths discovered at *Bath*, in Somersetshire, will serve to negative the question as to any Wroxeter supposed baths. At *Bath* the central bath was 90 feet by 68, flanked on each side by two baths, each 40 feet by 34; moreover four small semicircular baths and four vapour baths, each 36 feet by 20; add to these 24 small apartments for dressing and other purposes, and the accommodations at the hot springs in ancient Bath [*Aquæ Solis*] will not be deemed contemptible.

These circumstances prove that the Romans were aware of the fertility of the valley of the Severn, having in the middle of this extensive basin of country chosen the station of Wroxeter, where a branch of the Watling-street crossed the Severn, and proceeded through the narrow pass under the Caradoc Hills, at the Strettons, towards Ludlow and Hereford.

While the castle repairs were in progress, the county magistrates determined to build a new gaol. Some years before, the benevolent Howard had, by unwearied exertions, acquired a sort of general control over gaols and hospitals: he had introduced an entirely new system as regards classification, air, diet, and all that can contribute to the morals, health, and even comfort of the prisoners, as far as is consistent with safe custody; and as county gaols at Oxford and Gloucester had already been built upon his principles, the Salop magistrates procured a plan (from Mr. Haycock, a Shrewsbury builder), intended to combine similar objects; and as the site was adjacent to the castle, they engaged me to superintend the execution. Previously to the commencement of the work, Mr. Howard, in the course of his visitations, came to Shrewsbury, and upon examining the plan for the new gaol, he directed me to inform the magistrates, that, in his opinion, the interior courts were too small, and not sufficiently ventilated; also that the boundary wall should be at a greater distance from the buildings. He likewise noticed sundry inferior matters as to the chapel, &c. Upon my making this statement to the magistrates, they directed me to alter the plans, so as to embrace the several objects pointed out by Mr. Howard, which was accordingly done, and the work being carried on with all practicable expedition, was finished in 1793. Messrs. Scoltock and Carline executed the several works by contract. This gaol being situated immediately on the banks of the river, has the benefit of free

air and plenty of water; and although sufficiently clear of the town, is within the reach of aid, when required. Thus its general situation is excellent, the only defect being its distance from the County Hall, where the assizes and sessions are holden, so that the prisoners are necessarily conveyed through the streets of the town.*

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* While Mr. Telford resided in Shrewsbury Castle, under the patronage of Sir William Pulteney, an accident happened in the town, which ought to find a place in his biography. The collegiate and parochial church of St. Chad was founded by the kings of Mercia in the seventh century, upon the final conquest of Shrewsbury by the Saxons, and the edifice was burnt in the reign of Richard II. by the carelessness of a plumber, who did not (as is too usual) escape with impunity. He was terrified at seeing the church in flames, and in his flight attempting to ford the Severn, was drowned. The church was rebuilt, and after four centuries, in the year 1788, one of the four pillars which supported the tower in the middle of the church was observed to crack in various places; these alarming appearances in the mother church of the town, created general anxiety, and Sir William Pulteney sent Mr. Telford to inspect the state of the fabric. His report to the assembled Parish Vestry was, That in consequence of graves having been dug in the loose soil, close to the shallow foundation of the N.W. pillar of the tower, it had sunk so as to endanger the whole structure, and that the ruin of the church must speedily ensue, unless it were immediately secured by a thorough repair; and he recommended that the bells should be removed and the tower taken down forthwith, so as to permit the shattered pillar to be restored and secured, when relieved from the vast superincumbent weight.

But the Parish Vestry which met in the church on this occasion, exclaimed against such an expensive proposal, and some of them imputed interested motives to Sir W. Pulteney's Scottish architect; upon which Mr. Telford left them, saying, "That if they wished to discuss any thing besides the alarming state of the church, they had better adjourn to some other place, where there was no danger of its falling on their heads." The Vestry then proceeded to direct a mason to cut away the injured part of the pillar, in order to underbuild it; and on the second evening after commencing this infatuated attempt, the sexton was alarmed at the fall of lime-dust and mortar when he attempted to raise the great bell for a knell on the decease of a parishioner. He left the church immediately, and the next morning (9 July 1788), while the workmen were waiting at his door for the church key, the clock struck four, and the vibration produced by the motion of the chime-barrel brought down the tower, which overwhelmed the nave of the church, demolishing all the pillars on the north side of it, and shattering the rest. It was now perceived that the walls and pillars of the church, as is seen in many such ancient structures, consisted of a mere outside coating of freestone, the interior being filled with a mass of rubbish which crumbled into dust. Among this, and in the very heart of the pillars, were found stones rudely carved, which were evidently of Saxon sculpture, and had been ruins of the ancient church, thus applied in building the second church in the reign of Richard II.

I now became regularly employed as the surveyor of an extensive county, which from its being intersected by one of the most considerable rivers in the Kingdom, with sundry inferior streams falling into it; the bridges required for the intercourse of a populous vicinity, are numerous, and their maintenance requires a considerable levy of county rates, although the greater proportion of them being over the secondary streams, are of moderate dimensions: but the rebuilding of a Severn bridge is an important and expensive undertaking.

The first of these, of which, as county surveyor, it became my duty to furnish a plan, and afterwards to superintend the execution, was across the River Severn, at Montford, about four miles west of Shrewsbury, on the road to North Wales. At this place the river channel is deep and narrow, and its bed and eastern bank are alluvial earth.

The bridge consists of three elliptical arches, one of 58 feet and two of 55 feet span each; it is 20 feet across the soffit,* and the river being subject to high floods, considerable difficulty was experienced in the foundations; but, cofferdams † being employed, the structure was

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The present church was entirely rebuilt in the interval from 1788 to 1798, but in a manner which does no credit to the taste of the architect.

The catalogue is lamentable of ancient churches which have fallen from want of attention, and especially from grave-digging near the walls and pillars. The middle tower of the abbey church of Selby fell in the year 1690, and destroyed half the church. So at Whitchurch (Salop), at Banbury in Oxfordshire, Chelmsford in Essex, and at Great Shefford in Cambridgeshire. The city of Hereford was deprived of its principal ornament by the fall of the west tower and magnificent west portal of the cathedral, which suddenly became a heap of ruins in the year 1781; and the workmanship was too expensive for modern imitation, although the west end of the cathedral has been decently restored by a good architect.

* The soffit is the under-surface or ceiling (so to speak) of the arch, across which, as across the roadway and parapets, is, in fact, the breadth of the bridge.

† A cofferdam consists of two rows of piles, each row boarded strongly inside, and thereby resisting outward pressure when filled with earth, which, being well rammed and consoli-

rendered sufficiently secure. The whole is built of red sandstone, procured from Nesslife-hill, about four miles distant; it cost £.5,800. The contractors, Messrs. Carline and Tilley, being experienced workmen, it has proved a substantial edifice, having been completed upwards of forty years, and remaining quite perfect. Mr. Matthew Davidson was resident superintendent, and (as ever afterwards) well performed his duty. [*See* Plate 5.]

The next Severn bridge, rebuilt at the expense of the county, is situated about ten miles below Shrewsbury, at Buildwas, on a road leading to Wenlock. The old bridge was probably of the same age as the ruins of the adjacent Abbey, which is of Norman architecture, probably built by Roger de Montgomery, or his immediate successors.

While the low lands at the base of the Welsh mountains remained uninclosed, the floods speedily covered the flat lands, not deeply, but to a great extent of surface, and drained gradually off; but after these lands were embanked, and the floods were thus confined to the natural channel, they rose in it to a greater height, and passed off with greater velocity than formerly; this not only affected the bridges, but was injurious to the navigation, as affording too much water at one season, at another not enough.

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dated, is impenetrable by the surrounding water. In a space thus protected, bridge piers are founded on a timber platform, supported by piling. In small or shallow rivers, the whole stream is diverted into a side channel during a dry season; and some instances may have occurred, besides that of Westminster bridge, where piers have been built on shore, and floated to their final destination,—a hazardous enterprise, as no accuracy in under-piling the platform is thus practicable. A cofferdam constructed under circumstances of peculiar difficulty, is described in a subsequent part of this volume, as having occurred at the Gloucester Over-Bridge.

An uncommonly high flood in 1795, having destroyed the old Buildwas bridge, led me to consider a new mode of bridge-building, which had been introduced about 20 years before that time, when the Coalbrook-dale iron-masters and the well-known John Wilkinson, with a view of increasing their business, formed the project of making a bridge of cast-iron, to supersede a boat ferry across the Severn, near the village of Broseley; the expense to be defrayed by a joint-stock company. The iron-masters and architect deserve great credit for introducing a new material, and for the manner in which they erected the great ribs, each of which (in a semicircular arch of 100 feet span) consists of two pieces only; but they had not disengaged their ideas from the usual masonry arch, the form of which in iron is not graceful; nor does it offer sufficient resistance against the pressure of earth behind the abutments, which has pushed them forward, and thus raised the iron arch in the middle. The original design for this bridge (which formed an Era in bridge building) was made by Mr. Thomas Farnolls Pritchard, an architect resident at Shrewsbury; his grandson, Mr. John White, a London architect, has favoured me with the perusal of the original documents, dated 17th October 1775, and I consider it only justice to the ingenious artist to record his merit on this occasion; the bridge was commenced in 1777, and Mr. Pritchard died in October of that year. It was constructed, under contract, by Messrs. Reynolds & Darby, iron-masters at Coalbrook-dale; the practical operations were conducted by Mr. Daniel Onions.

In forming the design for Buildwas Bridge, the next bridge of cast-iron, I made the arch 130 feet span; the roadway rested on a very flat arch (the segment of a very large circle), calculated to resist the abutments (if disposed to slide inwards, as at Coalbrook-dale), while the flat arch was itself sustained and strengthened by an outer arched rib on each

side of the bridge, springing lower than the former, and also rising higher, indeed, to the top of the parapet railing, thus introducing more of the principle of timber trussing than of masonry. Each of the main ribs of the flat arch consists of three pieces, and at each junction they were secured by a grated plate, which connects all the parallel ribs together into one frame; the back of each abutment is in a wedge-shape, so as to throw off laterally much of the pressure of the earth; under the bridge is a towing-path on each side of the river. This bridge was cast in an admirable manner by the Coalbrook-dale iron-masters, in the year 1796, under contract with the county magistrates; the total cost £.6,034. 13. 3. [*See* Plate 6.]

Besides Montford Bridge and the Buildwas Bridge already described, forty smaller bridges were built under my direction, in the county of Salop; the dimensions of the water-way as follows:—

> " Two stone arches, 80 feet span each; three of iron, 55 feet; one of stone, 50 feet; four of stone, 40 feet; two of stone, 35 feet; one of iron, 27 feet; two of stone, 24 feet; nine of stone, 20 feet; and 16, less than 20 feet span."

I shall now proceed to describe two bridges of considerable magnitude, built about this time, under my direction; one over the River Severn, at the town of Bewdley in Worcestershire, where the old bridge being narrow and otherwise defective, and having also been injured by the great flood of 1795, the inhabitants applied for an Act of Parliament, enabling them to raise money upon pontage security, and therewith build a new bridge, better adapted to increased intercourse and river navigation, and the accomplishing of this was intrusted to me. The streets on each side of the river are upon low ground, the piers and abutments were to be founded upon rock, and good building stone was

procured on the banks of the river, a few miles above the town; under these favourable circumstances, I formed a plan of a stone bridge of three river arches, with land arches on the flat ground, for outlet of flood-water; the main arches were two of 52 feet and one of 60 feet; the breadth across the soffit is 28 feet; the land arches are nine feet span. Mr. John Simpson, of Shrewsbury, an eminent mason, built this bridge by contract; it was completed in 1798, and remains in a perfect state. Cost of this bridge, £.9,264. [*See* Plate 7.]

The other bridge was in Scotland, at Tongueland, near the town of Kirkcudbright, over the River Dee, where the tide rises upwards of 20 feet, the depth at low water being there 10 feet; the banks are high and rocky; it was here necessary to cross the river by one arch of 112 feet span. To support with centering* an arch of this magnitude was an arduous task, the water at an ordinary spring-tide being 30 feet in depth, and moving with considerable velocity; the arch was, however, successfully turned, without any accident whatever. The rise of the arch being considerable, caused high wing walls and deep spandrills; wherefore the mass of wings was perforated, and the pressure reduced by narrow arched openings; in the spandrills (instead of filling them with earth) were built a number of longitudinal walls, in fact interior spandrills, their ends abutting against the back of the arch-stones and the cross walls of each abutment; these longitudinal walls are connected and steadied by the insertion of tie-stones, and at a proper depth under the roadway the spaces between them are covered with flat stones, so as to form a platform for the road; and in these

* The centering of an arch is the timber frame which regulates its form, and on which its weight is supported until the key-stone is inserted at the crown of the arch. Experience in carpentry trussing is especially necessary to the architect in giving directions, safe with regard to the future pressure, and not unjustifiably expensive.

spaces are arched openings for occasional examination and repair (if ever it become necessary). I have ever since practised this mode, in order to lessen the weight incumbent upon large arches, and the pressure outward against high wing walls and spandrills; whereas formerly they were filled with soft spongy earth or clay, in consequence of which, at the bridge originally built over the North-Loch at Edinburgh (and also at other places), the side walls have been pressed outwards and actually thrown down. The external elevation of Tongueland Bridge is turreted and embattled. The total cost of the bridge's immediate approaches was £.7,710. The foundation-stone was laid 28th March 1805; the bridge passable November 1806. [*See* Plate 8.] It is worthy of remark, that in the mouth of the Kirkcudbright River Dee spring-tides rise 25 feet; whereas at other places, round the neighbouring coast of Scotland, spring-tides only rise from 14 to 16 feet; the trumpet-like shape of the sea entrance admitting so large a quantity of tide as cannot otherwise dispose of itself than by rushing up hill, as in the Firth of Forth, and more remarkably in the Bristol Channel.

About this time, the inhabitants of the town of Bridgenorth, in Shropshire, having determined to rebuild one of their churches, applied to me for a design. The situation is on a promontory of red sandstone; high above the river, the great Norman baron, Roger Montgomery, built a strong castle, of which some stubborn fragments, sloping from their base, manifest attempted demolition by gunpowder explosions; adjacent to these is the parish church of St. Mary Magdalene, originally, perhaps, the castle chapel. Upon this bold eminence the church is placed; the outside is a regular Tuscan elevation; the inside is as regularly Ionic; its only merit is simplicity and uniformity; it is surmounted by a Doric tower, which contains the bells and a clock; the

extreme length of the church is 124 feet, the breadth 67 feet, and the height of tower 115 feet. The total cost £.6,827. 11. 9. [*See* Plate 9.] The banks of the River Severn at Bridgenorth, are generally precipitous, and thickly clothed with trees, at intervals mixed with projecting rocks; one part of the town occupying the lofty ridge, while another part stands on flat ground on the opposite side of the river; altogether producing a very striking effect.

THE ELLESMERE CANAL.

[*See* Plate 10.]

The time was now arrived when my professional pursuits were to be in a great measure changed. Since the Duke of Bridgewater had (about the year 1760) introduced Canal navigation, it had made considerable progress in various parts of the Kingdom, and had been partially adopted in Shropshire. The advantages to be derived from this mode of conveyance did not escape the attention of the enlightened landowners, who aimed at accommodating their rich and thriving county with Canal navigation, so as to unite the Rivers Severn, Dee and Mersey; for which purpose, they caused the levels to be ascertained, and a plan formed; and so eager at that time were the public for Canal speculations, that, at the first general meeting, four times the estimated expense was, without hesitation, subscribed; and an Act of Parliament was obtained in 1793.

This project, in fact, consists of a series of navigations, under the name of the *Ellesmere Canal*, so called from that town being situated near the centre of operations; and the first meeting being held there, the description would be more correct by considering the canal as proceeding from the River Dee, in the vale of Llangollen, and passing near the towns of Ellesmere, Whitchurch, Nantwich, and the city of Chester,

to Ellesmere Port on the Mersey, in one direction; in the second, passing through the middle of Shropshire towards Shrewsbury upon the Severn; and in a third, proceeding by the town of Oswestry to the Montgomeryshire Canal at Llanymynech: in all, including the Chester Canal (as now incorporated), about 103 miles in length.

In planning a canal along the borders of North Wales, and afterwards on the summit which separates the counties of Salop and Chester, advantages in procuring water, and distributing it in the three before-mentioned directions, are not wanting; but many obstacles, from irregularity of surfaces and deep valleys, were to be encountered.

When the affair was so far arranged in 1793 as to justify the commencement of practical operations, the committee of management, composed chiefly of county magistrates, having, at the quarter sessions and other public meetings, observed that the county works were conducted to their satisfaction, were pleased to propose my undertaking the conduct of this extensive and complicated work; and feeling in myself a stronger disposition for executing works of importance and magnitude than for the details of house architecture, I did not hesitate to accept their offer, and from that time directed my attention solely to Civil Engineering. As most of the difficulties which occur in Canal making must be overcome by means of masonry and carpentry, my previous occupations had so far given me confidence; and in regard to earth work, I had the advantage of consulting Mr. William Jessop, an experienced engineer, on whose advice I never failed to set a proper value.

The accompanying Map shows the general outline of this inland navigation, and the several towns and districts accommodated by

it; to the northward, it communicates with the towns of Chester, Liverpool and Manchester; to the south, it is connected with the vale of the Severn, and eventually with the Port of Bristol, thus affording throughout an extensive circuit, the advantage of these great rival ports, and promoting mutually the interests of agriculture, manufactures and commerce, in which view a navigable communication had become urgently necessary, as part of the general system of inland navigation by which England is now beneficially divided into many islands, with ready access to the commodities and traffic of the whole mercantile world.

This Canal leaves the Cheshire shore of the River Mersey, about 12 miles above Liverpool, at a place now called Ellesmere Port; from thence to the city of Chester the distance is 9 miles, and from Chester to Nantwich 20 miles; thus far the canal and locks are made large enough to admit barges of 14 feet beam. A Canal from Chester to Nantwich was completed in 1776, but from defect of connexion with the adjacent country, and from its proximity to the Trent and Mersey Canal (which it was not permitted to join), this Canal lay useless until incorporated with the Ellesmere Canal in 1805. The perpendicular rise from low water at Liverpool to Nantwich is 177 feet.

From Nantwich to Whitchurch the distance is 16 miles, and the rise 132 feet; from thence to Ellesmere, Chirk, Pont-y-cysylte, and to the River Dee 1¾ miles above Llangollen (including the Prees branch), the distance is 38¼ miles, and the rise only 13 feet, in all 322 feet above low water at Liverpool. About 3¾ miles west of Ellesmere, at Frankton, the canal descends 30 feet, and from thence passes on a level to Weston Llulling Fields in one direction, and in another 10¼ miles to Llanymyneoch (with a fall of 19 feet), where it joins the Montgomery-

shire Canal. Except on the associated canal between Ellesmere Port and Nantwich, which carries boats of 14 feet beam, the canal locks and other works are calculated for boats of 7 feet beam only.*

The locks upon this canal are generally of the usual form [*See* Plate 11], excepting as to their gates; for having experienced that even those made of the best English oak in a few years are subject to decay, and that the renewal of them obstructs the navigation, considering also that iron abounded in Shropshire, and was more durable than timber alternately wet and dry, the uprights and ribs of the large lock-gates have for several years past been constructed with that material. For locks of 14 feet beam, the lower gates (being in two leaves) are cast heads and heels and ribs in separate pieces, with flanches,† and, being fastened together with nuts and screws, are sheeted with

* DISTANCE AND LOCKS:

	M.	F.	Y.	LOCKS.
Ellesmere Port to Chester	8	5	22	3
Chester to Nantwich	19	7	49	17
Bar Bridge to Middlewich	9	5	195	3
Nantwich to Whitchurch	16	1	54	19
Whitchurch to Ellesmere	13	3	93	
Prees Branch	3	6	198	
Ellesmere to Frankton	3	6	124	
Frankton to Chirk	7	1	130	2
Chirk to Pont-y-cysylte	4	1	98	
Pont-y-cysylte to Llangollen	4	—	88	
Llangollen to Llandisileo	1	6	66	
Frankton to Llanymonach	10	1	198	7
Frankton to Weston	6	—	83	
Rhuaben Railway	3	2	181	
	112	3	139	51

† Cast-iron work, whether ribs or pipes, or surface plates, is fastened together by means of flanches (flanking edges) at right angles with the surface plate or pipe  these flanches are screwed together by means of suitable holes and screw-bolts in the corresponding flanches; and besides the primary object of secure junction, strength is more cheaply attained by these flanches in the case of surface plates, than by uniformly thickening the entire plate.

wooden planking. For locks of 8 feet 6 inches rise, the lower pair of gates cost £. 102. The upper gates are cast each valve in one piece, and cost £. 59. 10. In the narrow 7 feet locks the lower gates are also cast as a single valve or leaf, costing £. 58; the upper gate is also one leaf or valve only, costing £. 28. 14.; these prices of the iron are computed at £. 14 per ton, delivered at the lock. Some of these gates have been in use upwards of 20 years, and show no symptoms of decay. The application of cast-iron has in one instance on this canal been carried to a still greater extent, nearly opposite to Beeston Castle, in Cheshire; where a couple of locks, together rising 17 feet, having been built upon a stratum of quicksand, were repeatedly undermined, which suggested the idea of constructing the entire locks of cast-iron; and this extraordinary application of a new material has been successfully accomplished, and answers the purpose [*See* Plate 11.] This mode, although expensive in the first instance, may in similar situations be practised with advantage.

I have given specimens of the lock gates, canal bridges, stop-gates and tunnel, for the information of the inexperienced, not that they differ from those on other canals, unless in a kind of stop-gate, which being drawn across the canal, may be shut in whatever direction the water is running. [*See* Plate 12.]

In regard to aqueducts, when a canal is carried over a small stream, at a sufficient height to admit the water to pass freely under it, they are constructed generally as a bridge of masonry, of sufficient breadth to admit a towing-path and puddle* to preserve the water in the canal;

* If this volume were addressed to canal makers only, and not also to the public, "Puddle," which is a technical word, denoting water-tight earth, would need no description. It is formed by wetting earth to fluidity in an inclosed space, and there turning and working

but when the level is so low in regard to the surface of the natural stream, as to require an increased head on the upper side, in order to force the water through a syphon under the bottom of the canal, much care is necessary; the foundations of the piers must be secured by platforms of timber and inverted arches, and from them are brought up iron ties, which being attached to iron ribs passed over the top of the arch, prevent the upward pressure from lifting the whole body of the masonry. When a navigable canal is carried over deep or wide vallies, an aqueduct becomes a formidable work, and demands all the skill of the Engineer. My previous experience of bridge building qualified me to conduct works of this description; but as each particular case requires peculiar treatment, Engineers, by adhering to one mode of construction, had sometimes met with serious failures, which were not only productive of disgrace to themselves, but involved their employers in disappointment and expense: these instances induced me to proceed with caution, and to study with great care the nature of each work.

The Ellesmere Canal being carried for several miles along the base of the Welsh hills, it was necessary to construct two aqueducts of great magnitude, one over the valley of the Ceriog, between Chirk Castle and the village of that name, and another over the River Dee, where it has worked its way (at some geological date) through the natural ridge of earth, which arrested and confined its waters in what is now the romantic vale of Llangollen.

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it with a shovel, until it has acquired that alluvial state which experience has shown to be requisite: it is then left to settle, and when the water has been evaporated from the sediment, a similar stratum of alluvial earth is superadded from time to time, and thus rises with the canal bank, in which it forms a concealed wall of earth, impermeable by water; in effect, it prevents leakage through a canal bank, or any dam or other earthwork which requires that kind of precaution.

The Ceriog, or Chirk valley, is 710 feet in width; the banks are steep, with a flat alluvial meadow between them, through which the river passes. To preserve the canal level, the surface of its water must be maintained at 65 feet above the meadow, and 70 above the water in the river. There are 10 arches, each of which is 40 feet span. The first stone of this aqueduct was laid on the 17th June 1796. Previously to this time, such canal aqueducts had been uniformly made to retain the water necessary for navigation, by means of puddled earth retained by masonry; and in order to obtain sufficient breadth for this superstructure, the masonry of the piers, abutments and arches was of massive strength; and after all this expense, and every imaginable precaution, the frosts, by swelling the moist puddle, frequently created fissures, burst the masonry, and suffered the water to escape, nay, sometimes actually threw down the aqueducts; instances of this kind having occurred even in the works of the justly celebrated Brindley. It was evident that the increased pressure of the puddled earth was the chief cause of such failures; I therefore had recourse to the following scheme in order to avoid using it. The spandrills of the stone arches were constructed with longitudinal walls (as at Kirkcudbright Bridge), instead of being filled with earth, and across these the canal bottom was formed by cast-iron plates at each side, infixed in square stone *

* Squared stone masonry is often called ashler work, and is opposed to rubble work masonry, of which the interior or core of thick walls, or the backing of walls which present only one surface to the eye, is composed. Rubble work denotes a mass formed of quarried stones, more or less irregular, as suits the occasion, and embedded in mortar: if in fluid mortar, the stones are small and irregular, and it is called grout-work, which is applied in strata or layers, as puddle work already described. It must be confessed that in ancient buildings, the freemasons, applied this species of economy of labour in an inordinate degree, when they filled supporting columns with careless rubble work. The fabulous apples of the lake Asphaltites were not so cruel a deception, the effect of which at St. Chad's Church (Shrewsbury) has already been told; but freemasons (be it remembered) were hutted by themselves around the edifice in progress, and fed there by their employers, until it was finished, and the contract price paid. Thus both parties

masonry. Those bottom plates had flanches on their edges, and were secured by nuts and screws at every juncture. The sides of the canal were made water-proof by ashler masonry, backed with hard burnt bricks, laid in Parker's cement, on the outside of which was rubble stone work, like the rest of the aqueduct. The towing-path had a thin bed of clay under the gravel, and its outer edge was protected by an iron railing. The width of the water-way is 11 feet, of the masonry on each side, 5 feet 6 inches, and the depth of the water in the canal is 5 feet. [*See* Plate 13.]

By this mode of construction, the quantity of masonry is much diminished, and the iron bottom plate forms a continued tie, and prevents the side walls from separation by lateral pressure of the contained water. There being a quarry of excellent flat bedded rubble-stone within a quarter of a mile of the site, and lime-kilns within two miles, the whole, with the exception of quoins, coping and lining the sides of the water-way, which are of ashler masonry, is of rubble work, laid in lime mortar; the materials and workmanship equally excellent. The edifice was completed in the year 1801, and is still in a perfect state; the total cost was £. 20,898.

This aqueduct is situated in a finely wooded valley, having Chirk Castle on an eminence immediately above it, with the Welsh mountains and Glen-Ceriog as a back ground, and the village of Chirk, with Lord Dungannon's seat and extensive woods in an eastern direction; the Holyhead road and Ceriog Bridge occupying the intermediate space. These combined objects compose a landscape seldom surpassed; add

had their reasons for expedition; present fame was acquired, and observations (such as these) felt to be many centuries remote, were disregarded. We are the more grateful for what remains to us of unimpeachable church architecture.

to this the boundary line of North Wales, with Offa's dyke in the immediate vicinity, whereby historical associations, the days of turbulence and savage warfare, are recalled with singular contrast to the blessings of domestic union, and well-regulated liberty, which produce an exalted grade of civilization manifested in the combined effort of hundreds of individuals, who invest their acquired property in making canals and other great national improvements.

About four miles north of Chirk, the aqueduct of Pont-y-cysylte forms a still more striking object than that which I have just described. The north bank of the River Dee at this place is abrupt; on the south side the acclivity is more gradual; and here, on account of gravelly earth being readily procured from the adjacent bank, it was found most economical to push forward an earthen embankment, 1,500 feet in length from the level of the water-way of the canal, until its perpendicular height became 75 feet; still a distance of 1,007 feet intervened before arriving at the north bank, and in the middle of this space the River Dee was 127 feet below the water level of the canal, which was to be carried over it; therefore serious consideration was requisite in what manner to accomplish this passage at any reasonable expense. To lock down on each side 50 or 60 feet, by 7 or 8 locks, as originally intended, I perceived was indeed impracticable, as involving serious loss of water on both sides the valley, whereas there was not more than sufficient to supply the unavoidable lockage and leakage of the summit level. To construct an aqueduct upon the usual principles, by masonry piers and arches 100 feet in height, of sufficient breadth and strength to afford room for a puddled water-way, would have been hazardous, and enormously expensive: necessity obliged me therefore to contrive some safer and more economical mode of proceeding. I had about that time

carried the Shrewsbury canal by a cast-iron trough at about 16 feet above the level of the ground; and finding this practicable, it occurred to me, as there was hard sandstone adjacent to Pont-y-cysylte, that no very serious difficulty could occur in building a number of square pillars, of sufficient dimensions to support a cast-iron trough, with ribs under it for the canal. After due consideration, I caused a model to be made of two piers, a set or compartment of ribs, the canal trough, the towing-path and side railing, with all the flanches, their nuts and screws and jointing complete. The foundations of the river piers are placed upon hard sandstone rock; those on each bank are either on alternating coal strata, or hard firm gravel. Thus secure of good foundations, suitable sandstone for the masonry, the best of iron, a satisfactory model of the iron work, and able experienced workmen, I proceeded with confidence of ultimate success, although the undertaking was unprecedented, and generally considered hazardous.'

The height of the piers above the low water in the river is 121 feet, their section at the level of high water in the river is 20 feet by 12 feet, at the top 13 feet by 7 feet 6 inches. To 70 feet elevation from the base they are solid, but the upper 50 feet is built hollow; the outer walls being only 2 feet in thickness, with one cross inner wall; this not only places the centre of gravity lower in the pier, and saves masonry, but insures good workmanship, as every side of each stone is exposed. I have ever since that time caused every tall pier under my direction to be thus built.* The width of the water-way is 11 feet 10 inches, of which

* Mr. Telford had seen evidence of the weakness of masonry supports which in appearance promised the utmost durability. The fall of St. Chad's Church, described in a former note (p. 26), disclosed to him in a striking manner the structure of its pillars, which were

the towing-path covers 4 feet 8 inches, leaving 7 feet 2 inches for the boat; but as the towing-path stands upon iron pillars, under which the

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of great diameter, but merely shells of masonry, filled with dry rubbish; nor indeed is such dangerous fallacy confined to ancient edifices, the rubble backing of the piers of Westminster Bridge (finished in the year 1745) scarcely supporting itself whenever the surface ashler work is removed for occasional repairs. Mr. Telford led the way in preventing much of this kind of fraud in bridge-building, by substituting longitudinal walls under the road-way, instead of filling the space with earth or rubbish; a great improvement, since adopted by all engineers. [*See* p. 27.] And whenever masonry piers are of sufficient dimensions to admit of apertures large enough for the convenience of the workman, and therefore also admitting subsequent examination of his workmanship, security is thus obtained, far more valuable than the questionable superiority of a solid mass, in which the true bearing and connexion of every stone is not of necessity brought to a test, as in a bonded wall.

Nothing in the history of masonry is more instructive than the duration of the Irish Round Towers, which will illustrate the excellent principle adopted by Mr. Telford; moreover they afford early instance of erecting such lofty buildings from within (avoiding the expense of scaffolding), as has recently been practised with decided economy in constructing steam-engine chimneys.

An Irish round tower in some instances exceeds 100 feet in elevation, and they may be said to average at 90 feet. Their outward circumference is about 45 feet at the base, where the thickness of the wall is from 3 to 4 feet, lessening upwards in a due degree to the summit. The expense of such an edifice (if now built) would not exceed £.300 or £.400.

About 120 of these towers are known to have existed in Ireland, and 90 of them still remain in various stages of decay, with the exception of a few still perfect, to the very coping-stone of the roof. These slender edifices (some of them) have withstood the wind and the rain and casual injury during 1000 years; for although the too frequent exaggeration of Irish antiquaries and historians has created very general incredulity, and, in consequence, inattention to what is really true of the Western Island and of its comparative civilization at an early date, it is highly probable that these towers were built in the course of 500 years preceding the Norman conquest of England: that they were Christian edifices, and in reality the bell-towers of ancient churches, is proved by their constant connexion with ruined churches and ancient burial-grounds in Ireland; and in Scotland, which received Christianity from Ireland, the church of Brechin affords example of a round tower annexed to the south transept, and now entered from it. Over the original entrance of this tower (closed with masonry when the church was built, and another doorway made) is sculptured, in rude relief, the Virgin Mother and her Babe.

The origin of these towers is from the Greek church; and the Turkish disciples of Mahomet adopted them under the name of *Minarets*, as convenient for the same purpose of summoning the faithful to prayer, substituting merely the well-trained voice of the Mollah for a small bell, not permitted by their religion. In the decline of the Con-

water fluctuates and recedes freely, the boat passes with ease. The stone piers are 18 in number, besides the two abutment piers; they were

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stantinopolitan empire, and long before the Turcoman invaders approached the capital, civilized occupations fled before them, and Greek architects were employed to adorn Italy with the magnificent churches and bell-towers of the middle ages. St. Mark's, at Venice, and its adjacent campanile, are perhaps some of the earliest productions of the Greek fugitives, who afterwards, in the confidence of their art, not only built round towers in Italy, but even built some of them purposely aslope from perpendicular, thus striking the mind of the beholder with an incongruous sensation of the known fact of their long duration and the appearance of immediate downfal.

There is no difficulty in supposing that some of the emigrant Greeks were attracted by the fame of Ireland, then the learned and the pious, to settle there, and imitate, in suitable manner, the parish churches of their native land in the East. Egypt, the most conspicuous member of the Greek church, was not likely to be deficient in religious edifices, and the most famous of her sainted hermits is distinguished as Simon Stilites, from his ascetic residence on the top of a pillar, in fact a round tower, connected with religious purposes. All things considered in a subject confessedly obscure, the best conjecture will perhaps attribute the date of the Irish round towers to the four or five centuries of which the reign of Charlemagne may be taken as the middle point.

The duration of these slender towers is worthy attention, not only of the antiquary, but much more of the architect. The first element of superior durability is seen in the large solid basement, or substruction, which was almost unavoidable from the position of the door-way at some distance from the ground; nor could the small diameter of the interior have admitted the entrance of timber spars for successive ladders, unless thrust upwards from a surface lower than the door-way. Among the 90 towers, which, in various states of decay, are still extant in Ireland, there are probably various specimens of the builder's art; the generality consist of that kind of careful masonry, called Spauled Rubble; in which small stones shaped by the hammer (in default of suitable stones at hand) are placed in every interstice of the larger stones, so that very little mortar is intermixed in the body of the wall, which is raised stage by stage of convenient height; the outside of spauled masonry especially presenting an almost uninterrupted surface of stone, supplementary splinters being carefully inserted in the joints of the undried wall.

The seemingly rude coverings of these towers are perhaps the best, that is, the most durable, ever devised by human wit. The arch familiar to the Greeks of the Lower Empire, could not be introduced where lateral abutment was impossible, and timber support was out of the question, so that the overlapping of flat stones consolidated by mortar into a hollow cone, was perhaps the only resource; and a few of these stone roofs still remain surmounted by their cap-stone.—A civil engineer, much connected with Mr. Telford's occasional missions to Ireland, has remarked, that the four windows (or narrow loop-holes) of these towers near the summit very exactly accord with the four points of the compass; but some of the towers have no more than two such windows; some more in number than four.

all built to the level of 20 feet, and then the scaffolding and gangways were all raised to that level, and the materials being brought from the north bank, the workmen always commenced at the most distant or south abutment pier, receding pier by pier to the north bank; and by thus ascending from time to time in their work, they felt no more apprehension of danger when on the highest, than at first on the lowest gangways; one man only fell during the whole of the operations in building the piers, and affixing the iron work upon their summit, and this took place from carelessness on his part.

By referring to Plate 14, the general form, and also the details of construction, will be readily understood. This singular aqueduct was opened in 1805, and has now been navigated 28 years with facility and safety; and thus has been added a striking feature to the beautiful vale of Llangollen, in which formerly was the fastness of Owen Glyndwr, but which, now cleared of its entangled woods, contains a useful line of intercourse between England and Ireland; and the water drawn from the once sacred Deva, furnishes the means of distributing prosperity over the adjacent land of the Saxons.

The whole expense * of the aqueduct, and great embankment, was £.47,018; a moderate sum as compared with what by any mode heretofore in practice, it would have cost.

	£.	s.	d.
* Expense of earthen embankment - - - - - -	8,570	15	8
Masonry - - - - - - -	21,162	13	5 ½
Iron work - - - - - - -	17,284	17	5 ½
	£. 47,018	6	7

The following inscription on a cast-iron plate, is inserted in the pier, next the south bank of the river.

The Nobility and Gentry of
the adjacent Counties,
having united their efforts with
the great Commercial Interests of this Country,
in creating an intercourse and union between
England and North Wales,
by a Navigable Communication of the Rivers
Severn, Dee and Mersey,
for the mutual benefit of Agriculture and Trade,
caused the First Stone of this Aqueduct of
PONT-Y-CYSYLTE
to be laid, on the 25th day of July 1795;
When RICHARD MYDDLETON, of Chirk, Esq. M. P.
one of the original Promoters of the
ELLESMERE CANAL,
was Lord of the Manor; and in
the Reign of Our Sovereign GEORGE THE THIRD;
When the equity of the Laws, and security of Property,
promoted the general welfare of the Nation;
While the Arts and Sciences flourished
under His Patronage, and
the conduct of civil life was improved
by His Example.

This inscription shows by whom, and in what spirit the general project originated, and never was a public work carried into effect with greater unanimity.

THOMAS TELFORD, F. R. S. L. & E. was Engineer.
MATTHEW DAVIDSON was Superintendent of the Work.
JOHN SIMPSON and JOHN WILSON executed the Masonry.
WILLIAM HAZLEDINE executed the Iron Work.
WILLIAM DAVIES made the Earthen Embankment.

Upon the canal there are two short tunnels, one 500 yards, and the other 200 yards in length, both in the rugged ground between the rivers Dee and Ceriog; they are each 14 feet 7 inches high, and 14 feet wide. A towing-path is placed in these tunnels, which covers 4 feet 9 inches,

leaving 9 feet 3 inches water-way; but this path standing upon pillars, there is little interruption to the water-way and boat.

The general summit of the canal is supplied by a navigable feeder 6 miles in length, carried along the bank of Llangollen valley, from the river Dee at Llandisilio. To ensure a regular supply during the driest part of the seasons, without injury to the mills on the river, the lake called Bala Pool, which is 4 miles in length, and situated about 20 miles above Llandisilio, is retained at a certain level from the end of winter, by means of a regulating weir; and the water so kept up, is drawn off gradually whenever required for supplying the canal at Llandisilio. From the above-mentioned summit, which continues to Chirk, the canal descends, by lockage, into the Severn valley in a southern direction, and to the rivers Dee and Mersey to the northward.

Upon and adjacent to the summit level of the canal, along the skirts of the hills, are inexhaustible quantities of coal, lime and slate, which are now distributed over a great extent of rich agricultural country, the increased produce of which, is by the same canal sent to Liverpool, Manchester, and the manufacturing districts; and by it in return, groceries, foreign grain, timber, and all articles of commerce are brought back for the supply of a wealthy and populous country district.

Adjacent to the town of Nantwich (where the Ellesmere Canal joins the associated Chester Canal) the distance to the Trent and Mersey, or Grand Trunk Canal at Middlewich, is only 11 miles; but between these two canals, although by the 2d and 17th Geo. III. power was given to carry a navigable branch* to within 100 yards of the Trent and Mersey Canal, absolute junction was prohibited; this branch there-

fore remained unexecuted: but in the year 1805, when the Chester and Ellesmere Canals were united, and after the Birmingham and Liverpool Junction Canal was commenced, it became evident that the beforementioned prohibition ought to be removed; and by executing that branch, a communication opened, by means of the Trent and Mersey Canal, and the Duke's Canal, to Manchester. An Act for this purpose was obtained in 1826, and the works have been completed. This branch is 11 miles in length, with 44 feet fall; the locks are 82 feet in length, and 7 feet 6 inches in width; the canal 16 feet wide at the bottom, 36 feet at the water surface, and 5 feet deep; and this, as well as the Chester Canal, obtains its chief supply of water from the Dee, by the feeder which, as already said, skirts along the north side of the vale of Llangollen.

I shall now state the rates of tonnage authorized by the Act; but the company have thought a rate reduced by one-third (on an average) more advisable, and upon paying the rates thus fixed by the company, the canal may be freely navigated.

Rates of Tonnage.

For coal, coke, culm, limestone, rock-salt, per ton per mile, 1½ *d.*

Freestone, timber, slate, iron-stone, lead ore, iron-lead, per ton per mile, 2 *d.*

All other goods, per ton per mile, 3 *d.*

Fifty feet of round timber, and 40 of square timber, are taken as a ton; any fraction of a mile to be taken as a mile, and a fraction of a ton exceeding a quarter counted as a quarter.

These rates may be leased by the company; they may be lowered, but not raised higher than what is above specified.

Exemptions.

Dung, soil, marl, ashes or other manure, lime used in the lands through which the canal passes; but these exempted articles are not to pass any lock unless the water is flowing over the waste weirs.

The expense of haulage, or conveyance, on this canal, including boat, horses and men, is, upon an average, one-halfpenny per ton per mile; say 10*d*. per boat-load of 20 tons for each mile, exclusive of canal dues.

It was highly gratifying to me, after the aqueducts and other works were completed, the canal made generally navigable, and the accounts finally closed, to receive the following testimonial from the committee of management; it was printed and circulated in their last General Statement, in November 1805:—

" *Having now detailed the particulars relative to the Canal, and the circumstances of the concern, the Committee, in concluding their report, think it but justice due to Mr. Telford to state, that the works have been planned with great skill and science, and executed with much economy and stability, doing him, as well as those employed by him, infinite credit.*

(*signed*) *BRIDGEWATER.*"

THE CALEDONIAN CANAL.

[*See* Plate 15.]

After having been for ten years employed upon the Ellesmere Canal, and others of less importance, political circumstances occurred which led to my connection with a work of unusual magnitude.

France having by successful aggressions arrayed the whole of Europe, and especially the Northern Powers, in combination against her great

maritime rival, and there being no naval station of any consequence, either in the north of England, the whole coast of Scotland, or the north-west of Ireland, the enemy had it in his power to annoy those parts from the North Sea, by passing round the Orkneys; whereby the commerce of a considerable portion of the United Kingdom frequently suffered serious losses; these circumstances, and a desire to give employment to the Highlanders of Scotland, the urgency of which was at that time much pressed upon Government, caused the subject to be taken into serious consideration; and enlarged views were opened by the description of the singular valley, called the Great Glen of Scotland, which, commencing between the promontory of Burgh-Head in Elginshire, and Cromarty, passes through a succession of sea-inlets and fresh-water lochs (lakes) to the southern extremity of Cantyre, a distance of 200 miles, and in nearly a strait direction between the Naze of Norway and the north of Ireland. The whole of this extensive valley, with the exception of about 22 miles, being occupied by navigable waters, and the excepted space by a navigable canal, saves upwards of 500 miles of dangerous navigation, as compared with that by the Orkneys and Cape Wrath. Ships of war, were this track open to them, might in two days, from a station at Fort George near Inverness, reach the north of Ireland.

This remarkable valley has been noticed ever since the time of the Romans. In the curious map by Richard of Cirencester, composed in the 14th century, and founded upon Ptolemy's tables, a continued canal is represented along the whole valley, between the east and west seas, perhaps from the fleet of discovery sent by Agricola having seen the deep-sea inlets on each side of the island.*

* This is not a fit place for discussing the antiquarian question, whether the map of Richard of Cirencester is genuine, or an ingenious fiction by Bertram; whose notes on

That this valley has always been deemed an important position for the command or protection of the Highlands, is evident from the old castle of Inverlochy, that of Urquhart, the Vitrified Forts, and the modern establishment of Fort-William, Fort-Augustus and Fort-George, being all placed in it.

At last this remarkable valley attracted the attention of the Commissioners of Forfeited Estates, who in 1773 employed the justly celebrated James Watt to examine and report his opinion whether it was practicable to open a navigable communication between the several lochs and the tideways of the eastern and western seas; when that able Engineer reported in the affirmative, and recommended a canal of 10 feet depth of water; but the forfeited estates being restored in 1784, the projected navigation was neglected.

In the year 1801, for the reasons already assigned, Government employed me to survey the coasts of Scotland, also the interior of the country, and report generally as to their present state, and what improvements were most advisable. The result of my investigations comprehended the establishment of naval stations, improving or creating ports, constructing roads, building bridges, and opening a navigable communication along the Great Glen of Scotland, by the Caledonian Canal.*

This Report was laid before Parliament by the then Secretary of the Treasury (now Lord Bexley), a promoter personally and officially of

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the alleged text of his author and on the map, which is boldly ascribed to Roman origin, sufficiently prove his intimate knowledge of ancient British geography, and refer to authors of unquestionable authenticity.

* *See* Appendix [B.], T. Telford's Report, dated 15th March 1803, Caledonian Canal.

every scheme for the good of his country. The several propositions, after full and laborious investigation, terminated in establishing two Boards of Parliamentary Commissioners, one for making roads and bridges in the Highlands, the other for the Caledonian Canal; I was honoured with the confidence of both, and shall first discuss what relates to the Caledonian Canal.*

Murray Firth.

On the eastern side of Scotland, and nearly opposite to the entrance of the Baltic Sea, is the extensive bay called the Murray Firth, near the bottom of which is the commodious Harbour of Cromarty on the west side; and the Murray Firth terminates at the inlet of the Beauley Firth, defended by Fort-George, within which and Channery Point is a well-protected roadstead, with 3 to 10 fathoms water. This, with the adjacent bay or rather harbour of Cromarty, as an auxiliary, forms a very perfect and secure station for a squadron of small ships of war, or for trading vessels, whether bound to or coming from Ireland, or the western coast of England, by means of the Caledonian Canal, as connected with the North Sea or the Baltic.

Description of the Caledonian Canal.

About ten miles within Fort George, and one mile to the north-west of the mouth of the river Ness, the tideway of the Beauley Water is from 5 to 7 fathoms deep, and here, at the fishing village of Clachnacharry, is the entrance of the Caledonian Canal. In order to secure an entrance for vessels of 20 feet draught of water, at the top of neap tides, it was necessary, from the flatness of the shore, to place the tide-lock 400 yards from high-water mark, at the end of an embankment; and

* *See* Appendix [C.], List of Commissioners. *See also* Act 27th July 1803.

in constructing this lock, very considerable difficulties occurred, which will be afterwards described. I shall here only observe, that this sea or tide-lock is 170 feet long in the chamber, and 40 feet wide, and that its rise is 8 feet; from this lock the canal is formed by artificial banks, upon a flat mud shore, until it reaches high-water mark at Clachnacharry, where another lock of similar dimensions is placed upon hard mountain clay. Immediately to the south of this, is formed a basin or floating dock, 967 yards in length, and 162 in breadth; its area is about 32 English acres. It is furnished with a wharf-wall and warehouse at the south end, and its ample dimensions produced earth by excavation for its own banks, and also for supporting the adjoining locks, instead of having recourse to back-cutting.*

At the south end of this basin, the great north road passes over a swing bridge, and adjacent to it are the four united Muirtown locks, each 180 feet long and 40 feet wide, which together rise 32 feet, lifting the canal to the level of the surface water of Loch Ness, when in its ordinary summer state. From the top of these locks, the canal, 50 feet wide at the bottom, 20 feet deep, and 120 feet at surface water, is carried by easy bends in the rear of the insulated hillock of Tomnahuric, to the river Ness at Torvaine, where, by reason of a precipitous bank, the canal is constrained to occupy the former bed of the river, a new channel being made for it by removing the opposite bank, which at the same time produced earth for separating the river and canal; a great work, more than half a mile in length. The same kind of difficulty, but less in extent, is overcome in the same manner twice before the canal enters the small Loch of Doughfour, (six miles from Clachnacharry,) by a

* Where the water-level is such that the excavation of a canal does not furnish earth enough for its own banks, recourse is had to the nearest earth behind the base of the banks; and this excavation is called back-cutting.

regulating lock 170 feet long and 40 feet wide, actually placed in the old channel of the river Ness, which in this place was heretofore separated into a double stream by an island of gravel. Such a situation points out the difficulty of keeping an extensive lock-pit free from the influx of river water, the ordinary level of which was 20 feet above the necessary excavation. Mr. Davidson's incessant attention was necessary and conspicuous during this unusual operation in the years 1813 and 1814, as well as that of Messrs. Simpson, Cargill & Rhodes.

Between the small Loch of Doughfour and the outlet of Loch-Ness at Bona Ferry, the river has been deepened, chiefly by a dredging machine. Loch-Ness is about 22 miles in length, no where less than a mile in breadth; in depth varying from 5 to 129 fathoms, (a greater depth than is found between the Murray Firth and the Baltic Sea) its direction is strait, with several small bays of moderate depth, affording good anchorage, as at Urquhart, Invermorrison, and Port-Clare on the north side; and at Dores, the fall of Fyers, and the Horse-shoe on the south side.

At the south-west end of the Loch stands Fort-Augustus, on the north side of which the river Oich enters the Loch where the canal leaves it, crosses the glacis, and at the back of the village ascends 40 feet, by means of five connected locks, each 180 feet in length; from thence it passes along the south side of the river to the north-east corner of Loch-Oich.* In this distance of about five miles is the Kytra lifting

* The sameness of sound in English pronunciation of the words *Loch*, for raising the level of a canal,—and *Loch*, a lake, is somewhat perplexing;—in describing, or speaking of the Caledonian Canal, where both words so often occur, the most intelligible precept for oral distinction, may be deduced from the Irish manner of writing the word *Loch*, always *Lough*, and pronouncing it gutturally, as if ending with *f*.

lock, and a regulating lock, each 170 feet long, and 40 feet wide, and the channel of the river has been changed in two places; the breadth of Loch-Oich is inconsiderable and irregular; in some parts it requires deepening by dredging, especially where the river Garry falls in from the north, draining the whole of Glengarry, and having in its course Loch-Garry 6 miles in length, and Loch-Quoich 10 miles; the summit supply of water for the Caledonian Canal is therefore abundant.

Between the western end of Loch-Oich and the east end of Loch-Lochy, a distance of about two miles, the surface of the ground is about 20 feet above the water level, and, the depth of the canal water being 20 feet, there is 40 feet depth of cutting. Near Loch-Lochy are two locks, a regulating lock, and a lifting lock; the difference between the surface of the water in these two locks (although Loch-Lochy has been raised 12 feet) is nearly 10 feet.

At the south-west end of Loch-Lochy (which is 10 miles in length) there is a regulating lock as usual, and the canal is carried over rugged ground along the north-west side of the river Lochy, its line intersected by one considerable river, and by several mountain streams; the ordinary level of Loch-Lochy is continued along the canal to within one mile of Loch-Eil, where are eight connected locks, each 180 feet long, and 40 feet in width, and together falling 64 feet;* from thence the canal is continued on a level to Corpach, where are two connected locks, falling 15 feet, and a single sea-lock entering the tideway of Loch-Eil. The sill of this last-mentioned lock was laboriously excavated in rock, so

* This great chain of locks near the south-west entrance of the canal from Loch-Eil, was finished in the year 1819, and forms a mass of masonry, 500 yards in length, quite unparallelled in canal operations. These eight locks, each rising 8 feet, were not inaptly named by the workmen, *Neptune's Staircase.*

as to ensure a depth of 20 feet of water at high water of an ordinary neap-tide. The operations which were necessary in making this lock were entirely dissimilar, but not much less difficult than those at Clachnacharry, and are worthy of attention.

The connection with the tideway being to the westward of the general line of the valley, and at the rectangular turn of Loch-Eil towards Fort-William, a well-sheltered roadstead and good anchorage are here obtained. Loch-Eil and the Linnhe-Loch are inlets of the West Sea, and the latter joins the usual channel of navigation south of the Sound of Mull.

The navigation by the Caledonian Canal between the two seas was opened at the latter end of 1823; the eastern district had previously been navigated three years.

The Caledonian Canal locks are not only constructed on an unusually large scale, but, in consequence of localities, they afford useful information to the practical engineer; of this, the most important instances are, (1.) The sea-lock at Clachnacharry; (2.) The sea-lock at Corpach; (3.) The locks at Fort-Augustus; (4.) The magnitude of fabric of the before-mentioned eight connected locks:—And, the facilities of inland navigation, indeed inland navigation itself, principally depending on lockage, or the means of raising or depressing a floating vessel to a different level of water, I trust I shall stand excused if I preface any description of the series of the largest locks ever yet constructed, by narrating as clearly as I can the progress of this important invention.

A river, in its natural current, is more or less deep from circumstances which need not here be described, and its navigation is usually impeded

by shallows and rapids; inconveniences which the ingenuity of man has striven to overcome, ever since his boats became too large and too heavy for portage, as is still in use for conveyance by canoes in the North American fur trade.

The first expedient which occurred was to thrust the boat as nearly as possible to the rapid, and having well fastened her there, to await an increase of water by rain; and this was sometimes assisted by a collection of boats, which, by forming a kind of floating dam, deepened the water immediately above, and threw part of the rapid behind themselves. This simple expedient was still in practice at Sunbury, on the river Thames, since the beginning of the present century; and elsewhere the custom of building bridges almost always at fords, to accommodate ancient roads of access, as well as to avoid the difficulty of founding piers in deep water, afforded opportunity for improvement in navigating the rapid formed by the shallow water or ford; for a stone bridge may be formed into a lock or stoppage of the river by means of transverse timbers from pier to pier, sustaining a series of boards called paddles, opposed to the strength of the current, as was heretofore seen on the same river Thames, where it passes the city of Oxford at Friar Bacon's Bridge, on the road to Abingdon. Such paddles are there in use to deepen the irregular river channels above that bridge; and the boat or collected boats, of very considerable tonnage, thus find passage upwards or downwards, a single arch being occasionally cleared of its paddles, to afford free passage through the bridge.

In this sense of the word, the arches of old London Bridge were designated as *locks*, some of the widest of them being purposely closed up to low-water mark by sheet-piling, which (with the sterlings of frame-work, filled with rubble stones for protection of the piers,) retained

the river for some hours navigable to Richmond at high water, sometimes quite to Kingston.

The next degree of improvement was the introduction of modern locks, at first called for distinction *pound-locks*, wherein water is impounded between upper and lower gates, for the reception of the boat; and these pound-locks, improved by modern accuracy with side walls and convenient sluices, have not only rendered the Thames and most of our other English rivers navigable, but, by economizing the water requisite for the transit of boats shaped to the lock, have given rise and scope to canal navigation; that is, to water carriage, where no river or stream existed or does exist.

I shall now return to the Caledonian Canal, first calling my reader's attention to the obvious advantage of this expedient over the inclined planes, which custom, unconquerable in China, still retains on their great rivers, and on the magnificent canals connected with them, throughout that extensive empire.

The shore of Loch-Beauley at Clachnacharry has already been described as being very flat, so that it was necessary to carry the Canal, by artificial embankments, 400 yards beyond high-water mark, where the shore consisted of soft mud, into which an iron rod could be easily thrust 55 feet; it seemed impracticable to enclose by a wooden coffer-dam, a space for a lock 170 feet long and 40 feet wide, with the necessary recesses and wing walls; the elasticity of the mud preventing the usual process of pile-driving, by a rebound after every stroke of the engine; therefore it became necessary to adopt a new method, one at least which I had not known to have been elsewhere practised. Abundance of heavy mountain clay being found in the base of the hill

immediately above high-water mark, an iron railway was laid down, and the two banks of the canal were thus carried out from the shore into 20 feet depth of water at an ordinary neap-tide; and on approaching the site of the future sea-lock, these banks were united into one mass, and were thus pushed considerably beyond the extent which the actual lock would occupy; thus the weight of the incumbent mass of clay compressed the mud, and squeezed out the water. Upon this large mound a quantity of stone (afterwards used in the building) was laid, and the whole suffered to remain for about six months; during which time the mass had sunk about 11 feet, this being from time to time ascertained by a spirit-level, from a mark on the shore. After feeling assured that no further sinking would take place, the pressure sustained being much greater than that of the masonry of the intended lock, the stones were removed, and a lock-pit was excavated in the solid mound; a chain-pump worked by six horses, kept the pit clear of water till its depth was 15 feet; at that time a steam-engine of nine horse power was erected, which commanded the water; and the excavation was completed in June 1811. Before penetrating 30 feet below the level of high water, at ordinary spring-tides (as was necessary for the foundation work), the compressed mud had been removed to the depth of eight feet, and the small portion of water which filtered through the surrounding mound of earth (in which puddle walls had been carried up) was conducted in small gutters along the surface edge of the compressed mud, to the pump-well. As soon as the lock-pit was excavated, rubble-stone masonry was laid in water-lime mortar, to the thickness of two feet, in the middle of the lock-chamber, increasing to five feet thick on each side; upon this, the inverted arch of square masonry was laid, and the side walls were founded; after which the chamber-walls, counterforts, recesses and wing-walls were regularly carried up. The masonry in the bottom part

was worked in short lengths of about six yards, to prevent the compressed mud from again softening and rising up in the newly compressed space. This mud was readily penetrated by piles; but whenever the strokes of the pile-driver ceased during a few hours, no power could drive them further in, or draw them out. The masonry of the lock was successfully completed in 1812, the rise being 6 feet 8 inches; the gates were then hung, and the lock has been constantly worked, remaining always in a perfect state. This plan of compressing the mud, sinking the lock-pit in it, and when the lock was completed removing the mountain clay from the entrance, was invented and adopted from the necessity of the case, and was found, upon calculation, to have been less expensive than any cofferdam, even had that usual expedient been practicable.

At the western end of the canal, at Corpach, the construction of the sea-lock required very different consideration, inasmuch as it was found necessary to connect the canal with the tideway of Loch-Eil, on the north side of a rock, situated beyond high-water mark, and covered at three-quarters flood, and the lock was to be advanced into the sea far enough to admit of the entrance sill being laid upon the rock, and so that there might be 21 feet of water upon it at the high water of neap-tides. For this purpose a water-tight mound, faced with rubble stones, was carried from the shore, beyond the extremity of the lock-pit; between these mounds a wooden cofferdam was constructed. The clearing away of the gravel and mud and sand, the fixing the main piles, and placing the wooden frames securely in their proper places, were operations of considerable difficulty, and worthy of record, for the benefit of those who may be engaged in similar expensive works; I have therefore given the details in the Appendix (D.), in which occasion is taken also to insert two or three remarkable incidents connected with the Caledonian Canal.

In the middle district, at Fort-Augustus, the ground upon which the five connected locks are placed, consisting of loose river gravel, and the lower lock requiring its entrance sill to be fixed 20 feet under the surface of the lowest summer level of Loch-Ness, presented no common difficulty; and as, moreover, the river Oich occupied the intended site of the lower lock, these circumstances rendered the construction of the locks an arduous undertaking; but, there being no alternative as to situation, these physical difficulties were to be encountered, and I lost no time in proceeding with the work. The first operation, in the year 1814, was to turn the river Oich entirely to the north side of a small, low, river island, with an intention to occupy what was formerly the river channel with the three lower locks. By means of a small steam-engine of six horse power, a trial-pit was sunk to the depth of 18 feet, when the water overpowered an engine of twenty horse power; a pump-well was then begun, and an engine of thirty-six horse power was placed on it, which commenced working in August 1816, and the excavation of the lowest lock-pit was carried on with much energy, until stopped by the winter floods of the river Oich. Early in the year 1817, operations were resumed, and during the summer and autumn the masonry of the lock bottom and wings, also of the forebay, was securely placed; and in order more effectually to command the water, I directed a third engine of about nine horse power (which had been in use at the Clachnacharry sea-lock) to be erected; and when the excavation was more than 25 feet under the level of the surface of Loch-Ness, the gravel was so open that all the three engines were required to keep clear the pit, and no cofferdam could be so placed as to render any assistance.

Under the inverted arches and side walls of the lock chamber, rubble-stone masonry (as at Clachnacharry) was laid; but it was here placed upon and mixed with abundance of moss, in order to prevent the sand

from being forced upwards through the lock-bottom from the interstices of the coarse open gravel. At the latter end of the working season of 1818, the whole masonry of the lowermost lock had been built; also the inverted arch, and 14 feet of the side walls of the second lock; likewise the inverted arch, and six feet of the walls of the third lock: so that, unless for afterwards putting up the lock-gates, there was no further occasion for employing steam-engines at Fort-Augustus.

These three locks being an extreme case on a large scale, I have considered it my duty to record thus much in detail all the means employed, in hope that such particular description may prove useful to practical engineers, and also to impress on them, from my experience, that after the principal engineer has decided upon the most advisable outline of operations, very much depends upon judicious workmanship, and attention to practical suggestions; so that, in the cases here described, not a small portion of the success is due to Messrs. Simpson and Cargill, at Clachnacharry and Fort-Augustus, and to Messrs. Simpson and Wilson, (chiefly the latter) at the sea-lock and other locks at Corpach, and all the other works in the western district of the canal.

Having described the canal line generally, also the foundation of the three most difficult locks, and having given plans of a single lock [*see* Plates 21 and 22], I have only to add, that on the eastern side of the summit, the excellent sand-stone from Redcastle, on the north shore of Loch-Beauley, was used in all the outside facing work at Clachnacharry, and for all the principal stones at Fort-Augustus; but for all the backing at the former place, and the body of the work at the latter, laminated and indurated schistus was procured adjacent to the site of the locks, and some granite was used at the summit. For the works on the eastern and middle districts, good water-lime was procured from Lord Elgin's lime-

works on the shore of the Firth of Forth, above the Queensferry. For the use of the western district, the stone for the locks at or near Corpach was procured from a quarry of highly indurated schistus on the shore of Loch-Eil, about four miles west of Corpach. This quarry even furnished stone sufficiently good for outside work, and the adjacent hill produced a sort of coarse porphyry for backing; the hollow quoins and coping-stones are of sand-stone from the Clyde, and excellent water-lime was found in the island of Lismore, in the Linnhe-Loch, about 20 miles from Corpach. Sand was procured from the shores of the fresh-water lochs on each side the summit.

The lock-gates [Plates 16, 17, 18] were made of English oak; but timber in sufficient quantity, of the scantlings required, and of sound quality, was not to be procured, although exorbitant prices had been paid for the sea-lock gates of that material. I therefore was by necessity led to employ cast-iron of the form and dimensions shown in the same Plates. For the eastern district, the iron-work (heads, heels and bars) was cast and fitted at Messrs. Jessop's iron-works, at Butterly in Derbyshire, and sent by canals to Gainsborough on the Trent, and from thence by sea to Inverness; and afterwards (when the canal became so far navigable) to Fort-Augustus. For the western district, the iron-work was cast and fitted at Mr. Hazledine's foundry, near Pont-y-Cysylte, in Denbighshire, sent by the Ellesmere Canal to Chester, and from thence by sea to Corpach. Thus the work was regularly supplied, to the extent of 14 locks on the west side, and 13 locks on the east side of the summit. The timber sea-lock gates were made, and those of iron were fitted, planked and hung, under the able superintendence of Mr. Thomas Rhodes. The bridges (except the foot-bridges on the lock-gates) are cast-iron turn-bridges, the horizontal movement of which experience has proved

to be more convenient than that of the drawbridge.* The mountain streams, though sometimes descending in torrents, did not, in general, require large aqueducts. In one instance a considerable stream (the Loy) crosses the canal under three small arches, and an extensive embankment. There is one let-off or outfall between Corpach and Loch-Lochie, at Strone. [*See* Plate 21.] It consists of three sluices, each four feet broad and three feet high; the sills are on the level of the canal bottom, and the inside faces at the water-surface, are ranged with the bank-line; the water, when issuing from the triple sluice, falls nine feet before it strikes the rock over which it tumbles, and creates an inundation over the flat land which here intervenes between the line of canal and the river Lochie. No artificial cataract exceeds the fury and the foam with which this issues from its rocky cavern. The frames and sluice-doors are of cast-iron, the working parts are faced with copper, the sluice-doors are raised and lowered by rack-work, enclosed in cast-iron cylinders placed above the centre of each, and rising one foot above the surface of the canal when full. The effect of this let-off in lowering the canal, is as follows: the length operated on is 6 miles; when there is 10 feet water in the canal, it is 50 feet wide at the bottom, and 80 feet at the surface, and the three sluices, when fully opened, lower the water as follows: viz.

From 10 to 9 feet	- -	in 1 hour	and	39	minutes.
„ 9 „ 8 „	- - -	1 „	-	42	„
„ 8 „ 7 „	- - -	1 „	-	45	„
„ 7 „ 6 „	- - -	1 „	-	49	„
„ 6 „ 5 „	- - -	2 „	-	6	„
„ 5 „ 4 „	- - -	2 „	-	38	„

* For the details of machinery and utensils employed, cranes, waggons and the like, see Plates 19 and 20.

In other respects, this canal differs from others chiefly by its dimensions, which, in deep cutting, embanking and linings, created a great expense.

The fresh-water lakes in the line of this navigation, although advantageous, as forming 37½ miles of its length, yet, by causing eight junctions, created much labour and expense, and great difficulty to the engineer. By means of dredging-machines, these entrances, as well as the shallows in Loch-Oich, have been cleared, so as to admit vessels drawing 15 feet of water; but in sundry places a further excavation of 5 feet is required, in order to obtain 20 feet, as originally intended, and for which the canal, with its locks and bridges, is adapted.

I have explained in the Appendix (E.) why the construction of this great work has occupied so many years, and also nominally cost nearly double the sum at which it was originally estimated. The chief cause was the unprecedented warfare in which all Europe was involved during the time the works were in progress; the value of materials and labour rising from 30 to 50 per cent., so that the sum annually granted remaining the same, only one-half the quantity of work could be annually performed.

The total expenditure, from the commencement in 1803 to May 1829, was,—viz.

	£.
For work performed by contract and measure - - - -	652,494
Ditto - - - - - day-work - - - - - -	68,099
	£.720,593
Expenses of management, in timber, machinery, shipping, land purchased, &c. &c. - - - - - - - -	261,766
	£.982,359

There had been received up to May 1829:

Rent of land and houses - - - - -	£. 5,359	£.20,300
Canal dues - - - - - - - - -	14,941	

Previously to the canal being made, strange opinions existed respecting the violence of the winds, and their blowing for several months in the same direction along the valley; and therefore, with a view of ascertaining facts, registers were kept at each end and in the middle of the valley, in which was noted, (1.) The direction of the wind in the valley; (2.) The direction of the clouds; (3.) The description of weather; (4.) The strength of the wind. This statement being partly printed in the Annual Reports of the Commissioners, shows that the winds are more variable in this valley than in the open sea, and not more violent; and for upwards of seven years this navigation has been used at all seasons, without any accident taking place; and as to facility of transit, steam-packets and even sailing-vessels have passed from sea to sea in 24 hours; and Inverness has become accessible from Glasgow with entire facility and regularity of passage.

Thus, this great and difficult work, performed in twenty years, in a remote district, and under a variety of other disadvantages, is proof of what may be accomplished by judicious arrangement and steady perseverance; but it must be acknowledged with regret that the Caledonian Canal has not accomplished its primary and national object, in facilitating the conveyance of Baltic timber to the western ports of Great Britain and to Ireland. The hostility of the northern nations of Europe interrupted our commerce with the Baltic, and in the year 1806 caused the British Government to permit the importation of timber, duty-free, from Canada, during two years prospectively. This permission was prolonged for a like term in 1808, 1810, 1812, 1814; and when at length peace arrived, the capital invested in the Canadian timber trade was successfully pleaded in Parliament as a good reason for continuing a duty almost prohibitory on Baltic timber, the price of such timber having been raised from 2*s.* 6*d.* to 7*s.* per cubic foot.

Thus the expense incurred in making the Caledonian Canal became of no avail; a trifling national detriment, indeed, compared to the vast damage inflicted by the compulsory substitution of bad timber in place of good timber for all the many purposes to which deal-balk is convertible. The separation of Canada from the mother country may perhaps hereafter remedy this evil.

THE GLASGOW, PAISLEY AND ARDROSSAN CANAL.

In the year 1804, after making arrangements for the progress of the Caledonian Canal, I was requested by the Earl of Eglinton, and others, to examine a project for making a canal from the city of Glasgow to Saltcoats, on the northern shore of the Bay of Ayrshire (and eventually to Ardrossan), passing near the manufacturing town of Paisley; the promoters of this scheme having observed that from Glasgow to Port Glasgow and Greenock, the river Clyde was so shallow as to oblige large vessels to tranship into lighters their cargoes 20 miles below the city. It is also evident that the river below Greenock turns southward at nearly a right angle, which was frequently the cause of detention by contrary winds; while by the shape and practicable level of the country, the distance between Glasgow and Ardrossan by Paisley was not greater than that between Greenock and Glasgow.

The length of the intended canal from Glasgow to Ardrossan is only 31 miles; in its course it passes through the manufacturing districts of Paisley, Johnstone, Lochwinnock, Kilwinning and Saltcoats, and thus has a dense population along its whole line, its summit level being only 110 feet above the level of the sea, in the bay of Ayr. At the request of the parties concerned, I caused a correct survey of the line to be made, and thereupon formed a plan for a navigable canal. [*See* Plate 22.]

The intercourse between Glasgow, Paisley and Johnstone being great, I proposed the canal to be upon one level along that distance of 10½ miles, that it might be without locks, and require water for the supply of evaporation and leakage merely. At Johnstone I proposed to ascend 64 feet to the summit, and on that level to pass through a fine valley 19 miles towards the town of Saltcoats, and when arrived opposite to it, instead of locking down 110 feet into an inconvenient harbour, I carried the line 1½ mile further to a prominent and remarkable point of the coast, where stood the ruins of the old castle of Ardrossan, and where it was possible to form a commodious harbour in such manner that vessels might enter and depart with all winds, with immediate sea-room, having also the advantage of an asylum harbour (if necessary) at Lamlash, on the opposite coast of the Island of Arran. This plan was approved of, an Act of Parliament obtained, and the work placed under my direction; it was judged most advisable first to work upon the ten miles next Glasgow, because, when completed, this might be rendered productive; in this portion much cutting and embanking was encountered, and a considerable aqueduct was required over the river Cart, at Paisley. At the Glasgow termination is an extensive basin, with wharfs and warehouses; another at Paisley, and a third at Johnstone. This portion of the canal and its bridges is made for passage-boats nine feet wide, which are employed in this populous district.

The state of Great Britain, and indeed of all Europe, while this canal was in progress, was tending to a general derangement of business, so that the proprietors (chiefly manufacturers) found it inconvenient to provide money to carry on the other portions of the scheme, and the canal remains unfinished, terminating at Paisley, between which place and Glasgow it is usefully employed; and the harbour of Ardrossan

belonging to the Earl of Eglinton, his Lordship preferred constructing it wholly at his own expense, and keeping it distinct from the canal.

It is proper to add also, that since the time when this canal was commenced, the navigation of the Clyde is so much improved, that a canal navigation to Saltcoats is scarcely necessary; the river trustees, by constructing alternate jetties half-way across from the banks of the river, and employing a dredging apparatus, having obtained several feet additional depth, which enables large vessels to come up to the Glasgow wharfs at the Broomielaw; while the numerous steam-boats not only disregard every obstacle in the river, but, by towing vessels against adverse winds, remove all reasonable complaints as to detention.

This is a striking instance of the risk which exists in an active nation of undertaking any new work which requires much time in completion; for although it may be very hopeful when projected, yet so rapid has of late years been the progress of invention, that some novelty is frequently introduced which totally alters the case, and interferes with former establishments; for instance, no person in 1805 suspected that steam-boats would not only monopolize the trade of the Clyde, but penetrate into every creek where there is water to float them in the British Isles and the continent of Europe, and be seen in every quarter of the world, not excepting Africa.

This canal affords a remarkable instance of the rapid progress of invention:—The introduction of iron railways, traversed by locomotive steam-engines, having threatened to supersede the intercourse by navigable canals, induced an enlightened canal proprietor, Mr. Houston, of Johnstone, near Paisley, to adopt a scheme entirely opposite to the

received opinion respecting the motion of loaded boats upon canals; that is to say, he discovered and proved experimentally, that with increase of speed the proportion of resistance is not increased, but diminished; so that a loaded boat, moving with a velocity of ten miles per hour, requires less tractive force than the same boat moving at the rate of five miles;* this fact, well established, has enabled Mr. Houston, for several years past, to work passage-boats between Glasgow and Paisley with advantages much beyond the slow pace formerly in use; but while this new mode of conveyance was proceeding successfully and profitably, and was adopted on other canals, an equally unexpected discovery came into competition; that is, by running locomotive steam-carriages upon the turnpike-road between Glasgow and Paisley, and so conveying passengers in as short a time, and at a cheaper rate, than even the before-mentioned rapid passage-boats on the canal.

RIVER WEAVER NAVIGATION, BETWEEN NORTHWICH AND RUNCORN, IN THE COUNTY OF CHESTER.

[Plate 23.]

Having for upwards of twenty years had charge of the Cheshire navigation, it is proper I should give some account of the improvements which have been made under my direction. The river Weaver rises in the south-west part of Cheshire, and, after passing in a very crooked course by the towns of Nantwich, Northwich and Frodsham (all in this

* The sectional capacity of a boat increasing in depth as well as breadth, from the prow to her midship frame, the foreship, when drawn by a rope, is raised by the resistance of the water in her passage through it, and this increases with her increased velocity; insomuch that in very rapid motion through the water the entire boat is raised, and skims (comparatively speaking) on the surface of the water, thus encountering less resistance than when moved with less velocity. But this does not take place in motion communicated by sails, the forward pressure of which tends to sink the foreship into the water, as much as its own form tends to raise it, so that the line of flotation in well-formed vessels remains much the same, whatever be the speed acquired by means of sails.

county), it falls into the estuary of the river Mersey, a little below Runcorn, about 20 miles above Liverpool. From the western tide-lock on the shore of the Mersey to Winsford (above Northwich), to which the navigation extends, the distance is 24 miles, and the rise only 52 feet; but by the crookedness of the channel and the consequent defect of regular current, many shoals had been formed, rendering the navigation very inconvenient. As the principal salt-mines in England are situate in the upper part of this beautiful valley, the export of rock-salt and white-salt, and the import of coals for boiling off the latter, created a great intercourse; and the salt-mines being the property of influential persons, who reside in the vicinity, fourteen county gentlemen united in a scheme to improve the river, which has eventually proved highly advantageous to the whole county. This scheme consisted in advancing a sum of money, upon which they were to receive an annual return at the rate of six per cent., the surplus beyond legal interest paying off gradually the capital advanced, and after this and the current expenses of maintaining the navigation were paid, the surplus revenue was made applicable to the bridges and public works of the county. On these conditions an Act of Parliament was obtained in the 7th of George II. (A. D. 1734) authorizing the construction of locks and weirs between Frodsham and Winsford, which were accordingly constructed, and greatly facilitated the intercourse; for this accommodation was charged 12*d.* per ton on rock-salt (of 120lbs. to the cwt.),—on white-salt (112lbs. to the cwt.),—and on coal (24 cwt. to the ton).

The locks are ten in number, each 80 feet in length and 18 feet in breadth; the vessels employed in this navigation are about 260 in number, and are from 60 to 70 feet in length and 17 feet in breadth, drawing from 5½ to 6½ feet of water, when loaded with about 70 tons;

they mostly belong to the salt-mine proprietors; the rate of freightage, exclusive of tonnage-dues, is 2*s*. 6*d*. to 3*s*. the ton, from Northwich to Liverpool; from Winsford 6*d*. more. Groceries, cotton, &c., 5*s*. per ton; and to and from the Sankey Brook navigation, the freights are the same as to Liverpool.

The before-mentioned improvements were for many years deemed sufficient; for although the side-cuts were occasionally incommoded by sand and rubbish, brought down by the land-floods, this was readily removed; but between Frodsham and the river Mersey, the tide being prevented by locks and weirs from passing upwards, the reflux was not sufficiently powerful to maintain a clear channel to its outfall, for which reason the barge-owners applied for an artificial canal, to extend from near Frodsham Bridge to the Mersey, at Weston Point, below Runcorn, for which they agreed to pay two-pence a ton; such additional payment to cease when the expense of the canal should be paid. The trustees agreed to this proposal; an Act of Parliament was obtained in the year 1807, and this canal, with its basin at Weston Point, was completed in 1810; the length of the canal, from Frodsham Bridge, being three miles six furlongs. On this occasion I was employed by the trustees, and have ever since been honoured with their confidence. I recommended Mr. S. Fowls to them as resident engineer, and both the trustees and myself have had good reason to be satisfied with his conduct.

The new works performed under my directions are: (1.) Protecting piers at Weston Point; (2.) A sea wall, about a mile and a half in length; (3.) Two river weirs, viz. at Winnington and Saltersford; [*see* Plate 24.] and, (4.) Renewing the lock and wharfs at Witton Brook, near Northwich.

In regard to the piers at Weston Point, the entrance basin there being placed at a considerable distance from low-water mark, afforded no facility or protection to vessels entering or departing, so that the barge-owners, suffering inconvenience, complained that the improvement for which they paid the additional two-pence tonnage rate was not complete until protection was afforded at Weston Point; and, after much discussion, the trustees directed me to prepare a plan, as shown in the Plate; and this being approved, was carried into effect, and with the advantage of obtaining excellent sand-stone from the adjacent hill, the work was well executed, under the management of Mr. Fowls, and continues to give satisfaction to the parties interested.

Secondly.—The extent of the canal from Frodsham Bridge to Weston Point was unavoidably carried 2,000 yards in length, skirting along a very steep bank, exposed to the south-western gales, from a reach of upwards of ten miles of sea. The mode which had been adopted by my predecessor for protecting the canal bank was by paving the upper slope with rubble-stone (pitched on edge), without mortar; and this, in most cases, would have sufficed, but here, being so openly exposed to seaward, the waves worked through the rubble-stones, dissolved the marle of which the outer canal bank was composed, and caused the rubble-stone pavement to sink. Thus it became disunited, and was partly washed away, so that the want of protection endangered the canal. In this difficulty, I recommended that the old pavement should be entirely removed, and broken into small pieces, the external slope of the bank to be shaped into the declivity shown in the section, coated with these broken stones, and grouted with water-lime mortar; upon the bed so formed, a pavement of scabled (roughly dressed) stones, about eighteen inches in depth, was set also in water-lime mortar, and all the joints being grouted, a substantial water-proof surface was thus

formed, which the greatest storms could neither penetrate nor derange, as the experience of many years has now fully proved.

Thirdly.—Several new weirs were constructed in place of those which were become ruinous, especially the Saltersford weir. [*See* Plate 24.]

Fourthly.—In the vicinity of Northwich, at Witton Bank, the dissolved salt, pumped to the surface as brine, leaves a subterranean vacancy, and causes a frequent sinking of the locks, weirs, wharfs and bridges thereabouts. This effect has at several times taken place since the Weaver Navigation has been under my direction, and the locks and wharfs have been so repeatedly raised, that what was formerly the surface level is now lower than the very bottom of the canal.

The county of Chester has now for many years been profiting by the judicious arrangements adopted by the before-mentioned fourteen magistrates; and according to the County Report of 1830, it appears that, in one year, the sum of £.23,023 had been paid from the Weaver Navigation revenue in aid of the county rates. The expense of the works executed under my direction was as follows:

	£.
Protecting Piers at Weston	7,835
Sea-wall at ditto	17,000
Saltersford Weir	3,652
Winnington Weir	3,500
Improving other Weirs	2,163
Altering Frodsham Canal Bridge	800
Cutting off Bend between Winnington and Saltersford	1,500
Enlarging Anderston Basin	4,176
Cutting off Bend at Dutton	2,700
Improving Witton Brook where sunk, &c. &c.	7,227
	£. 50,553

HARECASTLE TUNNEL.

[Plate 25.]

Upon the Trent and Mersey Canal, which is in the vicinity of the last-mentioned navigation, a work of considerable magnitude was, about this time, entrusted to my direction. On the summit of the canal it is well known that the celebrated James Brindley, in forming the Trent and Mersey Canal, found it expedient to construct a tunnel through Harecastle Hill for a distance of 2,888 yards, at 197 feet perpendicular, under the highest surface of the hill. This tunnel, where largest, is but 12 feet high and 9 feet wide, so that a seven-feet wide boat, with a moderate lading, can scarcely pass through. The operation of thrusting a boat through this tunnel is by a class of men called *Leggers*, who lie on their backs on the top of the loading, and push against the roof and sides with their feet. This tunnel, from commencement to completion, cost no less than eleven years, so inexpert were the workmen of that day, although under the direction of an able master.

The inadequate dimensions of this tunnel were, no doubt, advisable in an untried project, and for several years after the navigation was opened, the imperfect and tedious passage was probably found sufficient; but, as trade increased, the delay and inconvenience became grievous. The time allotted for passing each way was two hours, and before the expiration of that time a great number of boats waiting for passage was usually collected, and, notwithstanding strict regulations, much contention and confusion took place. This continued to increase with the increase of trade, and loud complaints were made, which the proprietors (although profiting by very large dividends) for many years disregarded; and it

was not till after the threatened establishment of railroads, and the formation of rival canals, that they were forced into an expensive improvement.

Early in the year 1822, the Canal Company applied to me to examine Harecastle Hill, and report upon the practicability of making a second tunnel. I proceeded accordingly, and in the ensuing month of March reported it practicable and advisable; and after a pause of two years, in July 1824, I was authorized to recommend Mr. James Potter, an active, intelligent young man, as resident engineer, and Daniel Pritchard, a person of much experience in tunnels, as contractor. I also settled the terms of contract, and made arrangements for machinery and materials. The line of the tunnel contained 15 pit-shafts; the deepest pit [Plate 25] being 179 feet. This great number of pits was for the sake of expedition. During the year 1824 some of the pits were sunk, and part of the heading accurately driven. On the 21st of February 1825, the first brick of the tunnel was laid, and with such energy and success were the various operations prosecuted, that the last brick was laid on the 25th of November 1826, after which the towing-path was completed, and the passage opened to the public on the 30th of April 1827, not quite three years from the commencement of operations.

The length of the tunnel (which is parallel with the former tunnel, at a distance of 26 yards) is 2,926 yards; it is 16 feet in height, and 14 feet in breadth, of which 4 ft. 9 in. is covered by the haling-path, leaving 9 ft. 3 in. for the passage of the boat; and as the path is supported by small pillars, the refluent water readily passes under it. The tunnel is so accurately strait that its whole length can be seen through at one view, and the workmanship is so perfect that the

joinings of the separate portions in which the brickwork was built are seldom discernible, although, by means of 15 pits, it was carried on in several places at the same time, through ground of very different qualities.

The bricks being made of clay peculiarly good in quality, and triturated by machinery, and being carefully molded and burnt, are in fact the best *Newcastle blue brick*, the hardest and most durable of any made in England. They are laid in mortar made of Barrow lias limestone, ground in a mill, which, in setting, becomes impervious to water, so that, on a careful inspection on the 21st March 1829, the following Report was made by me to the Committee:—

'I walked along the towing-path, and by means of a lanthorn and 'candle examined the whole very minutely, and found that the tunnel, 'after being worked two years, remained in every part quite perfect, 'so that in all the 2,926 yards I did not observe one crack or fissure, 'or even one decayed brick, which, in a work of such magnitude and 'difficulty, performed in the short period of three years, is, I venture 'to believe, without parallel. Although the materials are thus excel-'lent, and every facility was afforded, I consider it just to state the 'merit which is due to the resident engineer, Mr. James Potter, for the 'accuracy with which he set out the line, and his unceasing attention 'and perseverance in providing materials and conducting the works. 'David Pritchard fully justified his character as a contractor, in which 'he was ably assisted by his son-in-law, Mr. Hoof.'

In the Plate is exhibited the nature of the strata perforated, also the construction of the centering employed, and the manner in which the tunnel and approaches are completed.

The effect of the new tunnel may best be described by an anecdote; on occasion of my survey in 1829, a boatman, coming out of it, was asked for his observations and opinion; his reply was, 'That he only 'wished it reached all the way to Manchester.'

The expense of all the operations connected with this work, and of the tunnel itself, including a small heading driven through the hill, laying 6½ miles of railway, sinking and bricking 15 pits or shafts, excavating the space for, and constructing the centering and tunnelling, pumping water and completing the entrances, altogether cost £.112,681. [*See* Appendix, (F.)] I may observe in conclusion, that each of the tunnels being always navigated in the same direction, boats are no longer liable to interruption, and business proceeds with the same facility as on other parts of the canal.

THE MACCLESFIELD CANAL.

[*See* Plate 10.]

From the north end of Harecastle tunnel, a line of canal has been made, which, skirting the Derbyshire hills, passes by the manufacturing towns of Congleton and Macclesfield, to the Peak Forest canal at Marple.

At and near these towns manufactures had been early established, taking advantage of the waterfalls from the hills. These manufactures were not very important, being chiefly buttons made of silk or mohair; but more recently these have been superseded by the introduction of cotton and silk stuffs, and the number of inhabitants has increased accordingly; the population of Macclesfield, in the year 1801, having been only 8,743, whereas in 1821 it was 17,746; and in the census of

1831 its return was 23,129. In this populous district of Cheshire there was no water-conveyance, so that the manufacturers, being subject to the expense of land-carriage, they, as well as the land-owners, came to the resolution of making a canal in the before-mentioned direction. In the year 1825 I was employed to examine the face of the country, and decide upon the most advisable line; this done, on the 21st July in the same year I made a preliminary report of its practicability and general direction. I also framed instructions for a regular survey, which being accomplished, I was enabled to make a final report, with an estimate, on the 1st December 1825; and these being approved, an Act of Parliament was obtained, and the works have been successfully completed.

The canal is 29 miles in length, arranged in the following manner:—From Harecastle tunnel it is carried to the town of Congleton, and somewhat farther, 10 miles upon one level, to the north bank of the river Dane, where it ascends 114 feet by eleven locks, which in succession occupy about one mile. From the upper lock, at the distance of five miles, the canal passes the town of Macclesfield, and proceeds on a level to the Peak Forest Canal at Marple. By this arrangement, it is evident that the whole distance is divided into two levels, one, 10 miles, by which all the traffic in and near Congleton has access to the Trent and Mersey Canal, without lockage; while on the upper level, the numerous works in and near Macclesfield are supplied with coals from near Marple, also without lockage; and in a southern direction, by passing down the locks on the north bank of the Dane river, its trade proceeds along the lower level to the summit of the Trent and Mersey Canal, carrying to it both business and water; so that at the northern extremity, by means of a regulating lock, a few inches higher than the Peak Forest Canal, that canal is also furnished with water;

and for both there is an abundant supply from the continuous range of hills above the Macclesfield part of the canal; which canal is 16 feet wide at the bottom, and 32 feet at the surface of the water; it is 5 feet 4 inches deep, and the dimensions of the locks are 84 feet in length, and 7 feet 6 inches breadth.

In passing along the skirts of a mountainous country, and preserving therein the proper levels, this canal crosses several deep ravines, which require formidable embankments; these are ten in number, from 31 to 80 feet high, with corresponding aqueducts; one of these is of cast-iron. This canal, by means of the Peak Forest and Huddersfield Canals, is connected with the west riding of Yorkshire, and by the Ashton Canal with Manchester.

THE BIRMINGHAM CANAL.

[Plate 10.]

In the year 1824, I was employed by the Birmingham Canal Company to plan and direct the several improvements requisite to be made upon that canal; and in order to give a distinct idea of this complicated subject, previous explanation is necessary.

In the year 1766, an Act was obtained for a canal, commencing in the river Trent, at Wilden Ferry in Derbyshire, thence passing up the valley of the Trent, through the Potteries in Staffordshire, and down through Cheshire to the river Mersey, at Runcorn: and in the same year another Act was obtained for a canal branching from the last-mentioned at Heyword, near Stafford; thence passing by Wolverhampton to the river Severn at Stourport, a little way below the town of Bewdley, in the county of Worcester.

It is evident that, by forming a navigable communication from the town of Birmingham with those two canals, a navigable intercourse would be opened with the ports of Bristol, Hull and Liverpool, and with the Severn, the Humber and the Mersey. With this view, in the year 1768, an Act was obtained for a canal from Birmingham, through the mining district of Oldbury and Bilstone, to the Staffordshire and Worcestershire Canal, at Autherley, about three miles east of Wolverhampton. This work was prosecuted with such expedition, that coals were brought from Wednesbury and Tipton to Birmingham, in 1770; and the connection with the Staffordshire and Worcestershire Canal was opened in 1772. The Birmingham Canal was supplied with water by pumping from the coal-mines, and from a small reservoir at Oldbury; originally it was cut about 28 feet in depth through a ridge (1,000 feet in length) at the Smethwick summit; it was afterwards cut 18 feet deeper, but still the navigation of the canal was impeded by 18 feet of lockage (three locks up and three locks down) at the ends of a short summit. Between Birmingham and the Staffordshire and Worcestershire Canal at Autherley, the distance is 22 miles.

In 1783, an Act was obtained for a canal between Birmingham and the Coventry Canal, at Fazeley, a distance of 20 miles; this opened a communication with Hull; and afterwards, by the Coventry, Oxford and Grand Junction Canals, the various manufactured goods of Birmingham arrived in London by inland navigation.

Besides the two main lines, numerous branches were made to several coal-mines and iron-works, amounting in all to 28 miles, making the total navigation 70 miles.

The Birmingham summit is - - - -	464 ft.	5 in.	above low-water at	Liverpool.
„ Staffordshire & Worcestershire ditto,	352	3 - -	ditto - -	ditto.
At the Fazeley Junction, ditto - - -	219	- - -	ditto - -	ditto.

The Birmingham Canal was originally planned by the celebrated Mr. Brindley, and its numerous and inconvenient curvatures can only be accounted for by the consideration, that having rendered carriage by canals cheaper than by the bad roads then in use, it was not judged advisable to incur expense on deep cuttings and embankments, so as to shorten the distance, especially as the toll-dues were levied by the mile; and this effect of monopoly was not discontinued until rival navigations were opened, turnpike-roads improved, and railroads in immediate contemplation.

For several years after the canal was opened, it sufficed for the town and suburbs, but during the latter part of the last and beginning of the present century, the unprecedented increase of its manufactures and population,* created a corresponding increase of water-carriage, to which the imperfect canal was unequal, and the revenue being ample, the owners of mines, tradesmen and manufacturers demanded improved facilities.

Under these circumstances, the Canal Company, in 1824, applied to me to examine and report upon the most advisable means of improving the canal. Upon inspection, I found adjacent to this great and flourishing town a canal little better than a crooked ditch, with scarcely the appearance of a haling-path, the horses frequently sliding and staggering in the water, the haling-lines sweeping the gravel into the canal, and the entanglement at the meeting of boats incessant; while at the locks at each end of the short summit crowds of boatmen were always

* Birmingham, including the parishes of Saint Martin and Saint Philip, Aston and Edgebaston, by the Population Return of 1801, contained 73,670 inhabitants; in 1810, 85,755; in 1821, 106,722; and in 1831, 146,986; and the annual value of real property assessed, April 1815, was £.311,924.

quarrelling, or offering premiums for a preference of passage, and the mine-owners, injured by the delay, were loud in their just complaints.

Having duly considered this complicated subject, I found that in a great portion of the canal between Birmingham, the collieries and the iron-works, it was absolutely necessary for complete remedy that the numerous bends should be cut off, and the canal reduced to nearly a direct line from the town to Smethwick summit; that an entirely new cut should be made through that summit, 70 feet in depth; moreover, that the strait line should be continued across the flat ground, called the Island, and the ridge at Bloomfield, so that the general direction should become a strait and level line to Bilstone and Wolverhampton. This accomplished, the length of the main line between Birmingham and Autherley would be reduced from 22 to 14 miles, and adapted to unlimited increase of traffic; while the obsolete curvatures would be converted into separate branches or basins, accommodating the numerous mines on each side of the main line. By cutting down the Smethwick summit, I represented that the Birmingham level might be cleared of lockage embarrassments, and at the same time extended in its objects; I also proposed to enlarge the canal to 40 feet in width, with perpendicular banks, and by walling the sides, to ensure a good haling-path on each side, so that the entire line of this extensive summit should be covered with boats passing in different directions without collision; and this the more effectually, as the bridges, being 52 feet wide between the abutments, admit the haling-paths to pass in a direct line without any contraction of the water-way of the canal.

In prevailing on the managing committee to agree to these essential, though expensive, improvements, I was chiefly aided by the enlightened arguments of Mr. James Watt, whose grand steam-engine manufactory

being situated close to the canal, he was fully sensible of its imperfections, and convinced of the advantages to be derived from such effectual improvements. The general canal agent, Mr. John Freeth, who had been employed during most part of his life by the Company, and was zealously attached to its interests, also steadily supported this scheme of improvement, which was carried into effect in the space of two years.

The intercourse having thus been rendered perfect, the next object was to provide a plentiful supply of water to feed the summit level independently of the mine-owners, the former mode of obtaining water being a vexatious source of perpetual contest, besides creating a heavy expense in working pumping-engines. Upon examining the face of the country, I found a great extent of surface above the level of the canal, affording indeed a sufficient quantity of flood-water in rainy weather; but the reservoir at Oldbury was inadequate for intercepting and containing it, so that a great portion of the supply was lost. Therefore, in a dingle adjacent to the town of Birmingham, I constructed a reservoir of 80 acres water-surface, and 45 feet in depth at the head or retaining bank, the bottom of which reservoir was above the now reduced Birmingham summit, so that all the retained water became serviceable. To supply this reservoir, a feeder was carried from the before-mentioned reservoir at Oldbury, across ridges and dingles, in such manner as to intercept the flood-waters of the upper country, and conduct it to the great reservoir. Another feeder is brought from the southern end of the Oldbury summit, which conveys the surplus water from it to the great reservoir, and by which water may, when required, be returned to that summit. I have given a plan of this canal [Plate 10] in its former unaltered state, in the year 1824, showing also in what manner the various improvements,

executed under my direction, intersect and supersede the various curvatures, and have thus produced a remarkably strait line of canal. I have also given a transverse section of the reservoir embankment, and have delineated the discharging apparatus [Plate 29]; and the transverse section of the canal, as now improved, and of the haling-paths on either side of it, whereby boats pass freely in opposite directions, without collision or interference, are seen under the two bridges, of which elevations and sections appear in Plates 26 and 27. These are both of cast-iron, the one of 52 feet between the supporting abutments, a span which suffices to include both towing-paths; the other bridge is 150 feet between the abutments. The motive for this last extraordinary span was safety, combined with economy; for if it had not exceeded the span of the other bridges across this same canal, the abutments must have been founded as low as the bottom of the canal, because the bridge must have been carried up 70 feet to the level of the top of the banks, which would have led to an immense mass of masonry, liable to bulge and be overthrown in rainy seasons, by the earth acquiring a hydrostatic pressure; whereas, by increasing the span to 150 feet, there was opportunity of founding the abutments at a depth merely sufficient to admit of a proper iron-arch curvature; so that the proportion of masonry is small, and produces variety by its appearance of lightness, which agreeably strikes every spectator of the massive works under his examination. Another variety of bridge, not at right angles with the canal, called technically a *skew-bridge*, is represented in Plate 28. An aqueduct of cast-iron, carrying a canal of higher level, over the improved line of the Birmingham Canal, is worthy of examination.

All these improvements being now in full operation, have rendered this navigation a suitable auxiliary and accompaniment to this great manufacturing town, affording facilities well merited by its industrious

and ingenious inhabitants; and the result proves that, where business is extensive, liberal expense of this kind is true economy. Thus, from the canal office and wharfs in Birmingham (the centre of English inland navigation), this canal, for the space of seven miles, is rendered worthy of its position, and a specimen of perfect canal navigation.*

BIRMINGHAM AND LIVERPOOL JUNCTION CANAL.

[*See* Plate 10.]

The project for this canal originated in the year 1825, when a boundless rage for speculation had seized upon every object which ingenuity or invention could suggest; and as the price of iron was depressed, the iron-masters, to promote the consumption of that material, encouraged the construction of railways in sundry directions, the most important of which was a proposed line from Liverpool, through Birmingham, to London, all physical obstructions being forgotten or overlooked amid the splendour of this gigantic undertaking. Hereupon the canal proprietors became seriously alarmed, and consulted me as to the most advisable manner of protecting their property; and in considering the general state of canal communications in the central parts of the kingdom, it was evident that the trade between London and the Lancashire great towns of Liverpool and Manchester possessed only one line of intercourse north-west of Birmingham, and this by lockage downwards into the valley of the Trent, and from thence upwards to Harecastle Tunnel; and, after

* It was commonly said at Birmingham, in consequence of this improvement, that Mr. Telford ought to have had a public reward for introducing good manners among the boatmen, who formerly seldom passed each other without quarrels and imprecations, arising from the difficulty and delay of passing the towing-line under the inner boat; whereas they now meet and pass in good humour, and with mutual salutations.

passing it, descending again through Cheshire to Preston Brook and Runcorn to Liverpool in one direction, and in another direction, by the Duke of Bridgewater's Canal to Manchester. This route, therefore, is not only circuitous, but impeded by an enormous quantity of lockage. In stating this to the Birmingham Canal proprietors, I added, that the greatly increased business of their neighbourhood required a second and more direct line of communication, and that there was no other way of effectually protecting their property from depreciation by railway speculations, than by improving their old canal, and making a new one from near Wolverhampton, to pass in a direct line near Market Drayton in Shropshire, to Nantwich in Cheshire, from whence there was an existing canal through the city of Chester to Ellesmere Port, on the Mersey; that a branch should be also made from near Newport to the Shrewsbury Canal adjacent to the Ketley Iron-works, and another from near Nantwich to the Trent and Mersey Canal at Middlewich; that thus the varied but combined operations of all these canals would be united, and a second line of navigation opened to Liverpool and Manchester, shortening the distance 12 miles, and avoiding the delay of 320 feet of upward and downward lockage. This proposal was immediately adopted, and I was authorized to prepare a regular survey and estimates; and notices were given of an intended application to Parliament, for powers to make the Birmingham and Liverpool Junction Canal.

In the session of 1826, an Act was obtained accordingly, with the usual powers, whereby the Joint Stock Company was incorporated; and the canal was commenced, under my direction, as chief engineer; and Mr. Alexander Easton (formerly on the western district of the Caledonian Canal) was, on my recommendation, appointed resident engineer. John Wilson, an experienced contractor, obtained by

public competition, the first, second and third lots, or 21 miles of the northern portion of the canal; the remaining lots were undertaken by Mr. W. A. Provis, and partly by the above-mentioned Mr. John Wilson, both by public competition. The whole length of the canal is 39 miles, besides the Newport branch of 11 miles; it is 16 feet wide at the bottom, 36 feet at water surface, and 5 feet deep.

This canal takes its departure from the Staffordshire and Worcestershire Canal, nearly opposite to Autherley (where the old Birmingham Canal locks down into it), about three miles from Wolverhampton; from this place it passes on the same level three miles, in which is one lock; from thence towards Market Drayton, a distance of fifteen miles, the canal is upon a second level; near to Market Drayton are five more locks; beyond these, at Adderley, five miles distant, are also five locks; and at Audlem in Cheshire, fifteen locks in one chain; about two miles north of the river Weaver are two locks, making in all 28 locks on the main line, besides those on the Newport branch. Several aqueducts are requisite, none of great span or height, but of great length where they occur at high embankments; the locks are each 82 feet in length, and 7 feet 6 inches in width, so as to admit a seven-feet wide boat, carrying about 24 tons; these are represented in Plate 30, which also shows the section of the canal; and in Plate 31 appears the cast-iron aqueduct near Nantwich.

About thirteen miles from the southern end of the main line in the township of Norbury, the Newport branch goes off to the westward, and after passing through the town of Newport falls into the Shrewsbury Canal, in the township of Wappenshall; this part of the canal, including a subordinate branch, is 11 miles, and the fall is 139 feet; the canal locks are similar to those on the main line.

The Newport branch opens a convenient water conveyance from the Ketley and Lilleshall iron-works, whether their produce is to be sent to Liverpool or Manchester in one direction, or to Birmingham and London in the other. Formerly they had to send their produce by the Shropshire Canal and the Severn to Stourport, thence to ascend the Staffordshire Canal to Wolverhampton, and afterwards descend into the valley of the Trent, again ascend to Harecastle Hill, and afterwards descend through Cheshire 75 feet, before arriving at the level of the Birmingham and Liverpool Canal at the top of the Newport branch, after having travelled 86 miles, and passed through an extra-lockage (that is, upward and downward) of 570 feet.

The coal and lime from Ketley, Lilleshall and Donington Wood will thus be distributed along the eastern side of Shropshire. The Newport branch, by uniting with the Shrewsbury Canal, also opens a water-conveyance to all the central parts of Shropshire, and to North Wales, which districts thus obtain access to Birmingham and to London.

Besides the accommodation afforded by this canal to commercial and manufacturing intercourse, the agriculture of an extensive district between the Grand Trunk Canal at Stone and the Severn at Shrewsbury, a distance of about 30 miles, by being intersected in the middle at Newport and Market Drayton, will obtain lime and coals, and enjoy the other benefits of a convenient inland navigation.

This canal is supplied with water in the following manner:—its commencement and summit being upon a level with that of the Staffordshire Canal, and under that of the Birmingham Canal, communicating with the latter at Autherley, every boat passing to or from the Staffordshire Canal into the Birmingham and Liverpool Junction Canal, affords a

lock-full of water; and as this is received into the summit level, the throughout trade, or that down to the Mersey, is, for mere lockage-water, fully supplied; but as the lockage required for intermediate trade and shorter distances, and the unavoidable waste of water by evaporation and leakage, require a further supply, a reservoir of 50 acres is provided at Belvide, adjacent to the summit level, and another at Knighton, on the 15 mile level, near the origin of the Newport branch, also of 50 acres. These extensive reservoirs are indeed shallow; but, with the sundry occasional supplies from the adjacent lands in the course of 50 miles, they afford a reasonable assurance of the means of supporting an extensive trade, especially as the depth of water in the canal being five feet, it will, if necessary, admit one foot depth to be drawn off for lockage-water, in case of uncommon drought.

In order to counteract the effects of the several railways which, about this time, were proposed to be made between Liverpool and Birmingham, it became peculiarly desirable to carry the Birmingham and Liverpool Junction Canal in the shortest possible direction between the Birmingham Canal, near Wolverhampton, and the Ellesmere and Chester Canal at Nantwich, although this led to crossing the numerous inequalities of ground between the before-mentioned places, whereby this canal encountered cuttings and embankings of unusual magnitude, and proportionally expensive. In passing through Cheshire, the canal was, in this respect, peculiarly unfortunate; for the marly soil, of which the surface of that rich county chiefly consists, when used for embankment, slips and bulges in great masses, and rapidly dissolves when exposed to the atmosphere. From an unaccommodating disposition in some of the land-owners, in persisting to prohibit the proper line of canal, these evils were experienced to an enormous and unprecedented extent; and I am bound to state, for the benefit of engineers who may be engaged in

similar works, that to the height of 10 or 12 feet, it was found by experience, Cheshire marle retains its shape sufficiently well; but when the height required amounts to 50, 60 or 70 feet, no estimate can safely be made, and the enterprise ought not to be hazarded.

DRAINAGE OF THE FEN COUNTRY, AND ESPECIALLY OF THE BEDFORD LEVEL.

[*See* Plate 32.]

Having for ten years been employed upon sundry improvements in the drainage and navigation of the great Fen Level, in the counties of Cambridge, Norfolk and Lincoln, I have now to give a general description of the former and present state of this singularly interesting district. To enter at large into its historical details has occupied volumes; but sufficient information may be acquired by having recourse to the excellent Map, published in 1830, and accompanied by two octavo volumes, the work of Mr. Samuel Wells, who, in his office of registrar to the Bedford Level Corporation, has access to all existing documents, by means of which he has been enabled to select and record whatsoever is most valuable respecting this truly national improvement.

The great Fen district comprehends the low lands lying on each side of the bay called the Wash, which divides the counties of Norfolk and Lincoln, and occupies a space which, measured from Cambridge to a line drawn between Lincoln and Wainfleet, is about 60 miles in length, and not less than 20 to 30 in breadth. This extensive flat is bounded by the higher lands of the six counties of Norfolk, Suffolk, Cambridge, Huntingdon, Northampton and Lincoln; the area of the Bedford Level exclusively being about 530 English square miles, and therefore 400

square miles geographical,* or 340,000 English acres, and those the most productive in Great Britain.

Eleven natural drains or rivers carry off the high land waters, and may be enumerated from west to east; viz., the Witham, the Glin, the Welland, the Nene, the Cam, the Great Ouse, the Lark, the Brandon or Little Ouse, the Stoke and the Wissey. All these are collected into four outfalls; viz., the Witham, the Welland, the Nene and the Ouse.

The eastern high lands of Norfolk and Suffolk, as also the wolds of Lincoln, consist of chalk; directly westward, the high grounds are sandstone and oolite; the substratum of the great level is alluvial marle or sand, formed by the deposition of the upland waters, wherever met by the tidal waters. This deposit, when accumulated higher than the neap-tides, becomes salt-marshes, only overflowed by spring-tides; and vegetation, by partially intercepting the sediment of the upland waters, gradually raises the surface, and in process of time constitutes fens, through which, as being extensive flats, the rivers find their way with such uncertainty, as sometimes to form new channels for themselves. When the surface of the fen was thus raised to the highest

* The area contained in an English square mile as compared to that in a geographical square mile, is so nearly as three to four, that for all practical purposes that proportion may safely be used. It results from eight miles English being equal to seven miles geographical, as measured on the miles of latitude on the edges of every map; which also may be more safely referred to for the mensuration of distances on a map, than the avowed scale, which from too frequent negligence, or as being engraved on the copper-plate from an insertion on a proof impression, is frequently inaccurate; the last-mentioned cause of error arising from the shrinking of the damp paper of a proof-sheet.

By an easy application of the above proportions, it will be seen that the inhabitants of every civilized nation may ascertain the proportion of English measures of length and area with their own; so that mention of the geographical square miles in the text, will indicate to the foreign reader the extent of the Bedford level.

level of the spring-tides, vegetation and the deposit of upland floods accomplished the rest, until, during this process, the stronger plants and bushes established themselves, and formed a jungle; and considering the small advance of the natives from a savage state until the arrival of the Romans, and that the uplands were still entangled forests, we may safely conclude that these conquerors found the fen country a dreary expanse of such jungle of morass and bog. The Romans having conquered and explored England, and having retained possession of it for three centuries, had full opportunity of discovering the best means of improvement; and as the natives were not suffered to meddle with warlike operations, they are known to have been made unsparingly subservient to laborious purposes, especially to making military roads. Their masters being well acquainted with the value of the low lands of Italy, especially of those in the valley of the Po, it would readily occur to them, that by clearing and embanking these extensive fens, the alluvial or marly soil might be immediately rendered productive. Banks still attributed to the Romans are visible near Wisbeach and Lynn, and the Carr-Dyke may be traced almost from Peterborough to Lincoln; the line of forts or stations round the fens at Horsey near Stand-ground, at Erith, Bodsey and Worlich, in the parish of Ramsey, also in the parish of Willingham, afford convincing evidence of the estimation in which the Romans held the Fen district.

After the departure of the Romans, in the year 422, during the domination of the Saxons, Danes and Normans, nothing is known respecting fen drainage. Mankind seem, during 1,000 years, to have been unceasingly engaged in turbulence and war, the only patrons of civil improvement being the churchmen, who had established religious houses on the dry grounds which rise like islands in the fens, as at Peterborough, Ely, Ramsey, Crowland and Thorney; these places

having been selected chiefly for security from the rude warriors, partly no doubt for fishery, with freedom to cultivate and enjoy the produce of the lands attached to their religious communities;—and the churchmen having, in their journeys to Rome, had opportunity of observing the benefits derivable from embanking the estuaries of great rivers, and cultivating the low lands so gained;—having also the example of fragments of Roman banks at Wisbeach and at Lynn, we cannot suppose them so devoid of sagacity as not to attempt repossession of the fen lands, especially as a thousand years' additional accumulation from the upland floods and tidal waters had not only raised the surface of the fen land, but increased the marsh forelands outside the Roman banks, so that in deepening the Wisbeach River in 1635, the workmen, at eight feet below the bottom of the river, discovered in various places seven ancient boats; and at Whittlesey, eight feet under a peat stratum, was found a regular surface, with swathes of grass on it, as if newly mown. The ancient causeway from Denver to Peterborough is covered with moorish soil from three to five feet; and in founding the new sluice at Boston, a smith's forge and tools were found 16 feet under the present surface, and the roots of trees standing undisturbed in their natural position.

From the time of the Saxons until the Reformation, the care of the Fens seems to have devolved on the various monasteries there situate. In the reign of Henry VIII., an Act for regulating the Commissioners of Sewers was passed, but it specifies no powers for making new drains. In the reign of Elizabeth, the spirit of improvement began to revive, from the persecution of Protestants in the Netherlands, and from the massacre of St. Bartholomew in France; so that many foreigners in the 15th Elizabeth (1572) appear to have been settled in the vicinity of Wisbeach, Thorney and Whittlesey; and in the 20th Elizabeth an

Act was passed for draining the north level of the fens near Clowes Cross. In the 43d of Elizabeth (1600) a general Drainage Act was passed, extending to all the marshes and drowned lands in England. It is understood that this Act was originally prepared under the direction of Lord Burghley; but he dying in 1598, his aid was lost, and Queen Elizabeth died in 1602-3.

James I. then succeeded to the Crown, and in the second year of his reign he entered eagerly into the scheme of drainage, and agreed to a taxation of the Crown lands for that purpose; he then appointed Henry Totnall and John Hunt as commissioners, to treat with the parties interested, and Richard Atkins was employed to bore the fens 11 feet deep. The plan of drainage was to form a new channel for the Nene, from the town of March to its junction with the Ouse at Salter's Lode; also a strait channel from the Ouse at Erith to near the same place, where the Ouse at low-water was 10 feet below the soil of the fens: the first, called Popham's Eau, has since been executed; the latter is the Bedford River. Sluices were also proposed by him at the two branches of the Ouse, at the head of the New-cut; the land to be drained altogether, by Hayward's survey, being 307,242 acres. On the 13th of July 1605, Sir John Popham, Lord Chief Justice, Sir Robert Fleming, Chief Baron of the Exchequer, and others, were declared undertakers of the drainage of all the fens between the Ouse and Deeping, taking for their own share 130,000 acres. On the 5th of August 1603, Hunt and Atkins commenced Popham's Eau, which was opened 21st of December to Upwall, but early in the following year it broke its banks and was stopped. In 1606, a Bill was brought in to regulate the drainage, and Popham's Eau was enlarged. In 1613, a very high tide broke the dykes at Marshland, with damage to the amount of £.40,000.

Little effectual progress in draining the Fens was made during the remainder of this reign, but in the 6th of Charles I. (1631) it was resumed. A session of Sewers was held at King's Lynn on the 1st September, 46 commissioners being present, when a contract was entered into with Sir Cornelius Vermuyden for draining the Great Level, of which he was to have 95,000 acres. This man was a Zealander, his parents residing at St. Martin's Dyke, in the Island of Tholen, near the mouth of the Scheldt; he was brought over by James I., and his first work in England was embanking the Dagenham Marshes; he next undertook the drainage of Hatfield Chase near Doncaster, and accomplished it in five years, from 1626 to 1631.*

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* All discussions relative to the drainage of the Fens which centre in the county of Cambridge, are much embarrassed by the remnant of Vermuyden's practice, which is still pursued by many, for want of a public exposure of the misapplication of Dutch drainage, which has now prevailed in the Bedford Level during two hundred years; and although Mr. Telford, by clearing and regulating the Nene Outfall, has now practically shown the efficacy of a different principle, many Fen-men who see and admire that signal improvement, depart without acquiring such intimate knowledge of cause and effect, as should prompt them to go and do likewise; so that an unlearned and familiar exposition may not be without its use, and the sensible intentions of the early engineers in the time of Charles the First, supported by the recommendation of Kinderley in 1751, and of Brindley in his mature age, all pointing at Mr. Telford's adopted mode of drainage, may obtain due weight among the inhabitants of the Fens.

The Dutch province of Zealand (as its name seems to denote) consists mostly of land gained from the sea; so that the experience of its inhabitants in repelling the sea by embankments skilfully made and well protected, is derived from remote antiquity. Therefore after several attempts, and as many failures of those who undertook to drain the Cambridgeshire Fens, nothing was more obvious than to have recourse to Zealand for an experienced engineer, and Vermuyden was recommended to the King as deserving that character. Nor can we wonder that a man whose reputation was exclusively derived from Zealand practice, did not possess an enlarged mind and sagacity which would have shown him, that in the English Fens he had to deal with a case different in all things from Dutch drainage, except in the art of consolidating embankments and sea-walls.

To understand the aim of Vermuyden, the reader must call to mind that many great rivers carry to the sea such a quantity of alluvial earth as to form what is usually called a Delta (from the form of the Greek letter Δ), a word always used in speaking of Egypt and the river Nile; and the Danube in Europe, the Ganges and Burrampooter in India, and the river Amazon in South America, furnish instances of the same kind. Many other rivers,

Vermuyden being a foreigner, the inhabitants of the Fens violently opposed his being the undertaker, and petitioned the then Earl of

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equally well known, carry down no such quantity of alluvial earth, or they deposit it in such large or deep valleys at the entrance of the river into the sea, that the effect is not otherwise perceptible than by shoals or submarine banks, which require care and pilotage.

Other great rivers, of an intermediate character, deposit mud-banks wherever their current is met by the tide, which happens at very different distances from the river-mouth, in different states of the tide; and thus are formed mud-banks of considerable extent. These, in process of time, acquire such accretion as raises them to the level of spring-tides, sometimes above it, and thus they become subjected to the industry of man. Such are the islands which constitute the province of Zealand, alluvial deposits brought down from the southern part of Germany by the Scheld and the Rhine, the last of which rivers, earlier than the date of history, in its struggles to reach the ocean, created the province of Holland, still marked by ancient channels, and a small branch of the Rhine at Leyden.

The successive embankments, called *Polders*, which have secured and enlarged the Zealand islands, are still in progress, inasmuch that, in the year 1811, the inhabitants are known to have added two small mud-islands, and the intermediate channels, to the south-east part of Walcheren. No natural rivers exist in the flat surface of the Zealand islands, so that drainage is there confined to the simple process of pumping and discharging over the sea-wall all superfluous rain-water which falls on the *Polder*.

But the Cambridgeshire Fens presented serious difficulties of another kind; the rivers which water several counties have long since filled with alluvial deposit the space between Lincolnshire (which has its *Holland*) and the county of Norfolk; and as these rivers cannot turn aside, they must pass through or over their own deposit, and if impeded by nature, or the erroneous industry of man, they produce land-floods, which do much damage, and moreover create a constant expenditure in windmills and artificial channels to prevent the water from overtopping every embankment, drowning the cattle, and reducing this fertile region to general desolation. In more than one instance, a large tract of land is inclosed between banks for the more ready discharge of land-floods (which thus confined acquire a higher level), and to serve as a receptacle of water at the commencement of such flood. In ancient Egypt, prodigious excavations seem to have been made for the latter purpose, or to receive superfluous water when the rise of the Nile was excessive.

To such precautions Vermuyden naturally had recourse, and his Zealand habits had so strongly riveted his attention to danger from inroads of the ocean, that he inserted sluices and flood-gates at the end of all his drains, which being successively choked, have, from time to time, been replaced by others, and the natural river-courses thereby confounded one with another across the whole surface of the Fen. It did not occur to Vermuyden that the sea never rising above a height easily known from experience of the tides and winds, effectual safeguards are there practicable by banks of limited dimensions, while a land-flood rises indefinitely, and in proportion to the obstacles opposed to it. Hence it may be inferred that the true principle of draining the Fens, requires nothing more for its accomplishment than a free passage of all inland waters to the sea; which passage should be in as strait a direction as possible, because the current of water is

Bedford (who possessed 20,000 acres in Thorney and Whittlesey) to be at the head of a company of adventurers. The contract with the Earl is usually called the Lynn Law, and is dated 13th January 1630. Its authority is founded on a commission from the Crown, and it was ratified by the power and jurisdiction of the Commissioners of Sewers, and ultimately enrolled in the High Court of Chancery. The works executed by the Earl and his participants were as follows:—

1. The old Bedford River, from Erith to Salter's Lode, 21 miles long, and 70 feet wide.

2. Same cut, from Feltwell in Norfolk to the River Ouse.

3. A new cut near Ely, called Sandy's Cut, 2 miles long, and 40 feet wide.

4. Bevill's Leam, from Whittlesey-mere to Guyhorn, 10 miles long, and 40 feet wide.

5. Morton's Leam.

6. Peakirk Drain, 10 miles long, and 17 feet wide.

7. New South Eau, from Crowland to Clowes Cross.

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regulated by the declivity obtained; and it is evident if in a direct course three or four inches perpendicular in a mile, do but insure a moderate current, that a circuitous course of two miles between the same points will produce no current, and in dry weather become a weedy stagnant pool, as is experienced in inland drainage. The effect of the sea-tides, abandoned by Vermuyden to chance, below Denver-Sluice, on the east side of the Fens (now remedied by the Eau-brink Cut), and below Wisbeach Town on the west (now remedied by the Nene Outfall), may be seen on the general Map of the Fens (Plate 32), and more particularly in Plates 33 and 34; the respective channels to sea-ward having been circuitous, irregular and twice the length of a strait line; yet so prevalent and enduring has been the error of Vermuyden, that in the year 1814, Mr. Rennie, then at the head of his profession, did not venture to suggest a better remedy than a tide-lock below Wisbeach; which town, with its bridge and narrowed channel of the river Nene, continues to operate as an imperfect Sluice, less injurious in proportion as the obstruction is less complete.

8. Hill's Cut, near Peterborough, 2 miles long, and 50 feet wide.

9. Shire-Drain, from Clowes Cross to Tyd and the sea.

10. Two Sluices on the Shire-Drain; a clow at Clowes Cross; a great Sasse at the end of the well-creek at Salter's Lode; another stone sluice at the mouth of the Bedford River; a sluice at Erith; and above all, the great sluice at the Horse-shoe, below Wisbeach, to keep the tide out of Morton's Leam.*

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* The technical fen-drainage words in the above paragraph, and some others which elsewhere occur, seem to require explanation:—

Clow or *clough* (as plow, plough) is that kind of sluice in which the aperture is regulated by a board sliding in a frame and grooves, like a portcullis *(porte-coulise)* in ancient fortification.

Sasse is a navigable sluice; *sasser*, to sift, to pass through at pleasure.

Leam is an artificial cut or channel, whereby water is drawn or taken from its natural course, and carried in a direct line towards its outfall into the sea. Bishop Morton's Leam seems to have been the earliest, and he might have so named it from the Greek *λαμβανω*, sumo, recipio; whence is formed *λημμα*, the mathematical word for an assumed fact, and perhaps *leam*; but this derivation is uncertain.

Staunch or *stank*, an occasional stoppage of water by upright boards, or otherwise; the common phrase 'to stanch blood,' is the obvious derivation.

Gowt or *gote* is a limited passage for water, perhaps adopted from the common words 'gut,' or 'gutter.'

Lode is a word derived from the Saxon, and used in composition to express any thing which leads, as load-stone, lode-star, by which the mariner is led in his due course; and a drainage *lode* does the same thing with superfluous water.

Wash signifies a surface, sometimes, but not always, covered by water; thus the estuary into which water is discharged from the fens is called *The Wash*; and large spaces in the fens, inclosed by strong banks, which run parallel to the rivers at some distance, are called *Washes*, being in fact occasional receptacles for river-floods. They become necessary from the Vermuyden principle of obstructing natural outfalls by sluices; and a breach in the bank of a *Wash* inundates a large district. Dreadful misfortunes from this cause are remembered in the Fens, and the danger increases from the alluvial mud, which is always deposited by water retarded in its course, and which has raised the surface of the Washes six feet higher than that of the adjacent fen.

Foreland is a space left between the base of a bank, and an adjacent drainage cut or river, so as to favour the stability of the bank.

Catch-water drain, a trench with a bank on the lower side of it, carried horizontally along the slope of any rising ground, so as to prevent the water from above inundating the land below the said trench; and by such prevention securing, or at least facilitating, its drainage. Sir Joseph Banks used to say, that his reputation never did so much good,

In the 10th of Charles I. (1635) a charter of corporation was granted to the Earl and participants, and a general survey was made by Hayward, and delivered in upon oath in 1637. The Great Level was only to be made summer level. A session of Commissioners of Sewers, held at Huntingdon in the same year, declared the contract fulfilled, and ordered 95,000 acres to be set out, his Majesty's surveyor assisting; but the Earl was only to make summer lands. The Earl had always employed Vermuyden, who was very obnoxious in the Fens, but he had been employed by the King. The St. Ive's Law was reversed, and the King declared the undertaker, and to make winter lands; the works made by the King are as follow:

1st. A bank on the south side of Morton's Leam, from Peterborough to Wisbeach; a sluice at Stand-Ground, and a strait bank on

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as in enabling him to prevail with his country neighbours, so far as to influence 25 parishes to agree unanimously on the drainage of Wildmore Fen (north of Boston, in the county of Lincoln); these parishes all possessing some interest in the fen, as far as it was accessible. For the purpose of effectually draining the Wildmore Fen, which had no outlet, the late Mr. Rennie surrounded it and the adjacent fen lands, to the extent of 75,000 acres, with a catch-water drain. The lower part of this fen, to the amount of 15,000 acres, had always been in such a state as not to have been appropriated, and this watery waste has been formed into seven townships or chapelries by Act of Parliament, passed in the year 1812;—these townships contained 1,175 inhabitants in the year 1831. The land inclosed by the catch-water drain is supposed to be now worth £.50 per acre; a property of no small amount, partly created (as already described) and generally improved by the catch-water drain plan, never so extensively or more successfully applied than in this instance by Mr. Rennie, who thus increased the productive surface of Great Britain, in a manner which proved his superior skill in a very important branch of his profession.

Sir Joseph Banks considered that his share of the expense of the drainage (which in all cost £.650,000) amounted to £.100,000, and his final gain, by improvement of his landed property, to about £.200,000.

If some of the drainage words above explained do not occur in this volume, they will be found applicable to the general subject of fen-drainage, and especially to Sir John Rennie's Report (December 1836) on the proposed navigation of the river Nene to Peterborough, and the drainage of the lands adjoining.

the north side of Morton's Leam, at a distance of half a mile to a mile from it; thus leaving a *wash* upwards of 12 miles in length.

2d. A new river between the stone sluice at the Horse-shoe, and the sea below Wisbeach, 60 feet wide and 2½ miles long, with banks on both sides.

3d. A sluice on the Shire-Drain, below Tyd, afterwards swallowed by the quicksands.

These works, however, not having been completed, no drainage was effected; and the good Earl died in 1641, the victim of disappointed hopes.

Oliver Cromwell was born at Huntingdon, and, as a Commissioner, defeated the object of the Commission held by order of the King at Huntingdon, 12th April 1639. After the death of King Charles in 1649, an Act was passed for draining the Great Fens in the counties of Norfolk, Suffolk, Northampton, Cambridge, Huntingdon, Lincoln and the Isle of Ely, which finally settled the drainage. Oliver Cromwell used all his influence in favour of this Act or Ordinance, and was formally thanked by its other promoters.

Vermuyden divided the Fens into the North, the Middle, and the South Levels. The space between the Welland and the Nene rivers was called the North Level. The Welland was protected by a bank, beginning at Peakirk, extending to Crowland, and joining the Holland bank at Brotherhouse. This bank is 70 feet wide at the base, and 8 feet high. The waters are confined by a like bank from Peterborough to Guyhern; and on this occasion, the Shire-Drain and other water-

courses were scoured out and deepened, the outfall-sluice being placed at Tyd St. Giles.

The Middle Level, eastward of the river Nene, was protected by Stand-Ground Sluice, and by a bank from it to Guyhern, where it joins the great Waldersea bank. The waters of the Ouse were confined by a bank from the high land of Over to Hermitage, near Erith, where a sluice turned the upland floods north-eastward by Ely into the New Bedford, or Hundred-feet Drain, which commenced near Hermitage, and extended to Denver Sluice, with a bank on the south side, 60 feet wide at the base, 10 feet wide at the top, and 8 feet high; and another parallel bank on the north side, enclosing a space or *Wash* between them of 5,000 acres; added to these were Vermuyden's Drain of 40 feet, from Welshe's Drain to the River Nene, near Ramsey-mere, and sundry other drains. The Tongs Drain (or Marshland Cut) had sluices at each end; and in order to turn the tidal waters into the Hundred-feet Drain, and prevent them from flowing up to Littleport, Denver Sluice was constructed.

In the South Level, the principal work was a new river channel, 120 feet wide and 10 feet deep, from Denver Sluice to Stow Bridge, known by the name of St. John's or Downham Eau, and sluices were constructed at each end. Two new sluices were made at Salter's Lode, and the mouth of the Old Bedford river, to prevent the influx of the tidal water into the Middle Level; a dam was also made across the Old Bedford river, called Welshe's Dam, to turn the water of the Forty-feet Drain into the Old. Bedford river, or to the outfall at Salter's Lode. A great number of roads, bridges and forelands were made in all the fens. The forelands, in general, are 60 feet wide.

Sir Cornelius Vermuyden had the honour of knighthood conferred on him in 1629; and published his discourse as to fen drainage in 1642. He died not in affluent circumstances. His radical error was the substituting artificial strait cuts, and placing sluices upon them and also upon the natural rivers, instead of embanking the latter, and suffering the tidal waters to flow into the interior of the country; and in this he was suffered to persevere by the King, and afterwards by the Earl of Bedford, although against the opinion of all other engineers who were consulted. Bishop Morton had long before introduced the same principle by forming the Morton's Leam.

In 1658, Oliver Cromwell died, and on the Restoration in 1660, a temporary Drainage Act was passed; in 1661 another such Act, and in 1663 a general Drainage Act, establishing the Corporation of the Bedford Level.

The first mention of drainage by mills is in an order made at a meeting held in 1678, which bears that the surveyors of the Levels should each buy a mill; and in 1699, complaint was made of injuries from mills erected by one *Green*, near Slade Lode. From this time mills became universal. In 1713, Denver Sluice was undermined by the water, and blown up; nor was it rebuilt till 1748, from a plan furnished by Labely, the engineer and architect of Westminster Bridge.

The outfall of the waters of the Middle and South Levels having, for many years past, since the decay of Wisbeach, relied upon the river at King's Lynn, it was of great importance both to the drainage and navigation to preserve a deep channel; but, owing to Denver and other sluices preventing the flux and reflux of the tide, the lower parts of the river between Denver and Lynn had silted up considerably; and

even four miles below Lynn, although the river was wide, the navigable channel was circuitous, and impeded by shoals.

Many years previously it had been proposed by Mr. Badeslade to cut a new channel in a strait direction, between Lynn and St. German's Bridge, and thus (by shortening the distance nearly one-half) increasing the velocity, so as to create in the tide-way a power of scouring and deepening. Many conferences were held, and a variety of opinions expressed. The inhabitants of Lynn insisted that the increased velocity would sweep away the town, while the owners of fen lands dreaded the expense, and those interested in the navigation doubted the efficacy of the plan proposed; yet a Bill was brought into Parliament, and, after violent opposition, continued through two sessions, an Act was passed in 1795, the cost of obtaining which was then unexampled, being not less than £. 12,000.

Although an Act was thus obtained (known as the Eau-Brink Act), contention did not cease, and the limited time (being five years) was allowed to elapse without any practical operations being commenced, so that the projected improvements lay dormant during twenty years, until 1816 or 1817, when another Act was obtained, raising the tax to 2*s.* per acre, and extending the time; but as there are two distinct boards of Commissioners, one for drainage, the other for navigation, they each had the power of appointing an engineer, and Sir Thomas Hyde Page was employed for the navigation, Mr. Robert Mylne for the drainage. These engineers differed as to the dimensions of the intended Eau-Brink Cut, which therefore were finally determined by Mr. Joseph Huddart, as umpire.* Sir Thomas Page then resigned his office, and

* See copy of his Award in Appendix (G.)

Mr. R. Mylne dying previously to the commencement of the work, the late Mr. John Rennie succeeded Mr. Mylne, and in 1818 prepared the working plans and specifications, in which some progress was made; but in a short time renewed contentions determined the Navigation Commissioners also to appoint an engineer, and I was solicited by them to act in that capacity, to which, after some hesitation, I agreed, and, in concert with Mr. Rennie, directed the works until the cut was opened in 1821. This work was performed under contract by Messrs. Jolliffe and Banks, and by them also an extensive timber bridge was constructed over the lower end of the cut, in the middle of which bridge is a drawbridge to admit the passage of masted vessels. Although executed fully to the dimensions fixed by the umpire, the capacity of the Eau-Brink Cut was, upon trial, found to be too small for the river, and was, by my advice, enlarged one-third,* which was also performed by Messrs. Jolliffe and Banks, at an expense of £.33,000.

The effect of the new cut, after this enlargement, has exceeded expectation. During the first winter after it was opened, the river-channel from Denver Sluice to Lynn was scoured and deepened five feet, on an average; and the mud thus removed being met by the tidal water, at the lower end of the cut at Lynn (below the new timber bridge) was carried up the old river-course, and silted the upper part of it with a twenty-feet sediment in that short space of time; nor did this accretion of soil cease until nearly the whole of the old channel, about six miles in length and half a mile in breadth, was converted into valuable pasture. Between Lynn and Denver Sluice, the whole bed of the river Ouse, including the Eau-Brink Cut (which now forms the lower portion of that river) has since gradually deepened itself nearly

* See Report, July 1823, Appendix (G.)

fifteen feet, on an average; so that the outfall sluices of the drains on each side of the river, and the beds of the drains may now be lowered to a corresponding extent, and the expense and uncertainty of windmills may be in a great measure avoided. Advantage, however, has not been taken of the improved means of drainage afforded by the Eau-Brink Cut in the interior of the Middle and South Levels, so that there are nearly as many windmills as ever, but their efficiency is increased by the more rapid discharge of waters resulting from the improved outfall.

In regard to the town and harbour of Lynn, the effects of the new cut have been very different from what was expected by the alarmed inhabitants; for the new river, instead of undercutting the wharfs on the town side, has taken a direct course to sea, and thereby deposited a great body of sand and mud in front of the warehouses and quays, where the vessels formerly lay, which is felt to be a serious inconvenience; and this has happened, although the channel has been considerably restrained and narrowed by jettees, projecting from the opposite or west side of the river; so that, unless the quays are widened and brought forward, the jettees must be considerably extended.

The Eau-Brink works (previously to the last-mentioned enlargement) and the sluices on the South Level having all been set out and considerably advanced previous to my appointment, and the drainage Commissioners having the chief management, it is to their engineer, the late Mr. Rennie, that the planning of those several works is due; and he had the satisfaction to witness the cut successfully opened in July 1821. But that able and eminent man, after a long and useful life, sank under a lingering illness on the 16th of October of the same year. His son (then a young man) succeeded his father as engineer of drainage, and was associated with me in the remaining part of the business.

THE NENE OUTFALL.

Having acted as joint engineer with Sir John Rennie in conducting the execution of the Nene Outfall, and singly as the chief engineer in advising and executing the new drainage of the North Level, I must beg leave to give some account of the origin and progress of those works.

In the incongruous establishment for the management of the Bedford Level, jealousies, contention and confusion have been perpetually in action. It will be recollected that in the year 1697 the great level of the fens was partitioned by Vermuyden into the North, Middle and South Levels; an injudicious distinction, from the unavoidable connexion of the water-courses and banks of the several levels, and the opposition of interests thus created.

The North Level contains all that part of the Great Bedford Level which is situated between the north side of Morton's Leam and the south side of the river Welland. In the year 1728 the debt of the whole Level was £. 17,150; and in 1753 the Middle and South Levels were indebted to the Duke of Bedford and the Earl of Lincoln £. 18,000. Under the sanction of the Duke, the first North Level Act was obtained, the debts due to these noblemen were liberally cancelled, and the several accounts between the Levels and their creditors mutually adjusted; and to prevent the like difficulty from again occurring, it was provided that the lands of the North Level should be completely discharged from the payment of the residue of the debt owing in 1728, and from a debt of £. 13,000, contracted since that time, as well as from all other debts due by the Corporation for works in the North Level, and that it should not be thereafter liable to the payment of any debts contracted by the Middle or South Levels, nor those levels be subject to debts contracted by the North Level proprietors; and a separate body of commissioners

was created for managing the drainage of the North Level in a great measure independent of the original Bedford Level Corporation.

The North Level (including Portsand) is divided into five DISTRICTS, containing together about 39,622 acres of rateable or taxable lands. The *first*, containing 4,489 acres, is bounded on the west by the rising lands of the Soke or Jurisdiction of Peterborough, from which it is separated by the Car-Dyke; on the north by the river Welland, and a part of a drain called the Old South Eau; and on the east and south, by a ridge of land running from a place called the Black Horse to the town of Eye, where this ridge meets the ancient Car-Dyke.

The *second district* contains 3,643 acres, and is bounded on the north-west by the aforesaid rising lands; on the north by the said ridge and Thorney-Dyke; on the west by Car-Dyke; on the south by the Counter-Drain, and the north bank of Morton's Leam, and on the east by Knar-lake.

The *third district*, or Thorney-Lordship, containing 17,588 acres, is bounded on the south by Thorney-Dyke, and on the west by Catswater, on the east by Gold-Dyke, and on the north by the Old South Eau.

The *fourth district* contains 6,449 acres; it is separated from Thorney-Lordship by Gold-Dyke, and from the Wisbeach Hundred Drainage, by the Old South Eau; on the south-east it abuts against the Counter-Drain and the north bank of Morton's Leam; and on the opposite side, against the Old South Eau.

The *fifth district* (or Great Portsand) contains 7,451 acres, and is on the south bounded by the Old South Eau, on the north by Asen-

Dyke, on the west by the river Welland, and on the east by Shephay-Bank. This district is not part of the Great Bedford Level, but was united with the North Level, for the purposes of drainage by Act of Parliament in 1753.

The water from the above *five districts* was conveyed to Clows-Cross by the Old and New South Eau channels, and from thence by the old Shire-Drain to the river Nene, at Gunthorpe Sluice.

The general drainage works are under the control of the North Level committee, consisting of eighteen commissioners, six from the third district and three from each of the others; within the five districts were one steam-engine, and above thirty water engines.

The whole of the North Level contains about 48,000 acres, of which Newborough (5,276 acres) and Sutton St. Edmund's Commons, Flag-fen, &c. (in all about 3,000 acres) are exempt from the general North Level taxes.

Although Kinderley's Cut (executed in the year 1773), by rendering a part of the channel of the Nene more direct, and defining it to a regular width, improved both the navigation and drainage, yet as the outfall to seaward terminated above South Holland Sluice, it was obstructed by the great mass of sand at Sutton Washway, which rendered the navigation shallow and precarious, and, by choking and retaining stagnant water against the South Holland and Gunthorpe Sluices, subjected the lands in South Holland and in the North Level to an imperfect drainage. The sands at the washway continuing to increase, threatened in time to destroy the outfall of the Wisbeach River. This was not unobserved by the Duke of Bedford's agents, and the enlightened land-owners and occupiers in the North Level; they were also aware, that at

the distance of about four miles north of Sutton Washway, at a place called the Eye, the difference of level, when compared with the Sutton Washway, was twelve feet; so that, if the outfall of that river were carried on strait to that place, nearly twelve feet additional fall might be obtained. This at last became so obvious that the parties interested employed the late Mr. Rennie to investigate the matter, and report on a proper plan for the drainage of the North Level, and improvement of the navigation of the river Nene.

Mr. Rennie performed this important service in his usually careful and masterly manner; and, after causing the necessary levels to be taken, he furnished in January 1814 a general Report, in which he recommended the commencement of a cut at Crab-hole Eye anchorage; and entering the embanked lands at Lutton-Leam Sluice, there to construct a tide-lock for the navigation, with draw-doors and an extensive over-fall for the river, and proceeding by an artificial cut up the embanked marshes in a direct line to Kinderley's Cut, from thence to deepen the present river to the Horse-shoe; and from that place to pass (by another new cut) in a direct line to Rummer's Mill, leaving the town of Wisbeach considerably to the left, and from Rummer's Mill deepening and improving the channel to Peterborough. The Wisbeach Corporation were dissatisfied at the intended removal of the river from their town, and claimed the privilege of taking the opinion of another engineer.

It was on that occasion, in 1821, that I was employed by the town of Wisbeach to examine and report upon the improvement of the river, more especially adjacent to the town. On the 31st May of that year, after a careful inspection, I made a Report, in which I approved of making a new cut from Crab-hole to Kinderley's Cut, but preferred leaving an open-tide river to placing a lock at Lutton-Leam Sluice, as suggested by Mr. Rennie. From this cut, upwards to the Horse-shoe,

I proposed to deepen and regulate the channel according to his plan; but, instead of passing direct to Rummer's Mill, I recommended cutting off the acute angle at the Horse-shoe, and deepening the present channel up to the bridge at Wisbeach; and, instead of passing through the bridge, to keep to the left, and make a new cut along the bank on the south side of the town, and join the river again immediately above it, so that by a ship-lock at the present bridge, and an embankment and sluice, with draw-doors below the upper junction, the intermediate space would be converted into a floating dock, with the upper part of the town on each side of it, while the river would have an open channel through the lower part of the town, without such obstruction as the bridge and the present crooked and confined channel oppose against the flux and reflux of the tide and land floods. The plan was approved by the parties interested in drainage, but the whole scheme was postponed from the opposition of the Corporation of Wisbeach.

Early in 1822, I was applied to by that eminent barrister, Mr. William Adam, who had the charge of the Duke of Bedford's interests in the Fens, to make a complete survey of and report upon the river from Crab-hole to Peterborough. For this purpose I engaged Mr. John Gibb, whom I had many years employed on public works, and Mr. William Swansborough, an experienced builder and drainage engineer, resident at Wisbeach, and through them I procured complete and satisfactory documents.

Mr. Rennie having died the preceding October, and his son (now Sir John Rennie), a young man of promising talents, being associated with me, we made a preliminary Report on the 26th June 1822, by which it was shown that by making the Nene Outfall as proposed, South Holland Sluice (a Lincolnshire drainage outlet) might be lowered six

feet ten inches; Gunthorpe Sluice seven feet eleven inches, and the Black Sluice four feet two inches; that in the town of Wisbeach, at ordinary spring-tides, might be obtained from fourteen feet to fifteen feet of water, and from eight feet to nine feet at neap-tides; and that, by lowering the sills of the before-mentioned sluices, the North Level and South Holland would acquire a natural and perfect drainage.

There cannot be a stronger instance of the inconvenience and delay experienced in bringing to bear any scheme of magnitude, in which numerous and conflicting interests are to be consulted, than in the case of the Nene Outfall; it has been shown that, in 1814, it was agitated, and plans and reports obtained; that again, in 1821, it was eagerly discussed, but it was not until 1827 that the effectual Act of Parliament was obtained. At this time it fortunately happened that the Duke of Bedford, who, from his possession of Thorney-Lordship, has a preponderating influence in the North Level, had two intelligent and active agents in his legal adviser, Mr. Adam, and Mr. Tycho Wing (his resident steward), who, convinced of the advantages likely to result from this plan, not only to the Duke of Bedford, but also to the other proprietors of that Level, did not fail to persevere until they finally accomplished this important object; so that, in the year 1826, the mode of taxation having been determined, and the plans and estimates for the outfall between Crab-hole and Kinderley's Cut finally arranged, a Bill was brought into Parliament, which, after much discussion, received the Royal Assent on the 14th June 1827. The successful termination of this long-debated improvement was, no doubt, hastened by the Act for the Great Embankment, which carries a road across the Sutton or Cross-Keys Washway; which Act, chiefly by the indefatigable exertions of Lord William Bentinck, became a law on the 26th May 1826.

The Nene Outfall Act having been obtained, working drawings and specifications were immediately produced, and a contract entered into with Messrs. Jolliffe and Banks on the 2d July 1827.

The contractors for deepening the Nene Outfall commenced operations with their usual skill and activity, and in a short time 1,100 men were employed upon the work; and Mr. William Swansborough of Wisbeach, a man experienced in drainage operations, was, on my recommendation, appointed resident engineer. These arrangements being made, the excavation proceeded with rapidity and success; and the Duke of Bedford's judicious agent, Mr. Tycho Wing, having the chief management on the part of the land proprietors, none of those unpleasant altercations were experienced which too frequently occur during the execution of fen drainages.

During the year 1828, very considerable progress was made with the excavation, but when carried to a certain depth, the entire bottom was found to consist (as the borings had indicated) of mud and quicksand; it was thereupon suggested that the bottom might be scoured by the current of the river, as had taken place in the river Ouse upon opening the Eau-brink Cut; and under this impression the contractors proposed, that if permitted to deepen the bottom in this manner, they would carry the cut up to Buckworth Sluice, without requiring any additional payment; and as this would greatly improve the new river-course, the proposal was readily accepted. All this was successfully accomplished, so that, in the course of the year 1829, the works were carried to Buckworth Sluice. On the 4th of June 1830, the dam at the lower end being removed, and the upper dam on the 7th, the tide was admitted to flow up the new cut, and this so continued until the 14th; but while the river was permitted to pass partly down the old channel, there was not a sufficient rush of water down the new cut to scour

out the silt brought in by the flowing tide; so that it became absolutely necessary to close the old channel by making an embankment across it, so as to turn the whole of the river down the new cut. This I directed to be done with all possible despatch, and personally saw it commenced. A quantity of earth had been previously deposited on the western bank, and leave obtained to excavate back-cuttings from the embanked lands on the eastern side. Thus aided, the contractors, by employing about 300 workmen and 100 carts, and persevering night and day, performed this important service in six days; and it may be useful to remark, that in order to accelerate the formation of this bank, four or five old barges or lighters were sunk across the river-course. The embankment having been successfully completed, has on the sea-side of it accumulated a deposit of sand and mud, which continues rapidly to increase. At the lower end, from Skate's Corner to the Crab-hole anchorage, the channel is formed in a direct line, and perfectly regular. When these operations were finished, the slopes of the new Cut were protected by rubble-stone (partly brought down the river from Wansford, and a portion by sea from Yorkshire), and remained without injury from the tides or land freshes in winter.

At what time and in what manner the river Nene will be improved up to and past the town of Wisbeach, and from thence to Peterborough, is very uncertain, as the inhabitants of Wisbeach still inherit a full portion of the perverse disposition which Mr. Wells, in his History of the Fens (Vol. 2, page 677), records as heretofore forcibly obstructing the formation of Kinderley's Cut; instead however of the favourable change he would willingly attribute to the present generation, an equal degree of perverseness has lately been shown respecting a proposed improvement of the Woodhouse Marsh, which, although recommended by two experienced engineers, and repeatedly opened, has been so mismanaged by the order of the Wisbeach directors, that the whole

work has been nearly ruined, and great expense uselessly incurred. But this work at Woodhouse Marsh has since been finished (though not in the most skilful manner), and is now in use. This instance, and the violent opposition to my plan in 1821 for a new river-course and floating-dock, a measure calculated to improve and establish their port as equal or superior to Lynn, may serve to characterize a people, not only indisposed to promote the general improvement of the adjacent country, but totally incapable of judging of what would have been manifestly beneficial to themselves.*

* It may perhaps fairly be questioned, whether the above remarks in derogation of the inhabitants of Wisbeach are strictly justifiable; whether the question is not one of those in which both parties are so much interested as to leave room for moral arbitration between them.—A civil engineer is a zealous instrument in every extensive improvement, and the recent accession of numbers to that profession, of men who must possess much accurate and useful knowledge, is to be deemed an equivalent (nationally speaking) for all the losses now felt or expected from excessive speculation. But knowledge is progressive; and the existence of a body of civil engineers in England can only be dated from the patronage of Mr. Brindley by the then Duke of Bridgwater, the spirited projector of the Manchester canals, about the year 1760; and if it be true that Brindley gained little from the study of professional books, it is also true that such books did not then exist in the English language, and that his mind might have produced less of originality, had his opportunity of reading been more extensive. Mr. Smeaton was contemporary with Brindley, equal to him perhaps as a mechanician, and had just then proved his skill in masonry by completing the Eddystone Lighthouse. Thenceforward he was much consulted as a civil engineer, and in concert with Messrs. Grundy and Edwards (1761) made a report on the Witham (Boston) Drainage, then in ruinous condition. They recommended of course to straiten and enlarge the river channel; but the doctrine of Vermuyden prevailed with them, 'To stop the tides from flowing at all into the new 'river, that its depth and dimensions may be preserved;' and a sea-sluice, with three pair of doors 'pointing to seaward,' was the result. Smeaton, though much employed in drainage operations, never seems to have detected the erroneous principle thus adopted. Two years afterwards he reported on the Harbour of Rye in Sussex, which had been brought into special notice by the refuge afforded to a frigate in distress, on board which was King George I., in his passage from the Continent, in the year 1725; and an Act of Parliament was obtained, imposing a transit-toll on all shipping which passed that port and Dover. The Commissioners under this and a preceding Act 'for restoring the Harbour of Rye to its antient goodness,' were persuaded to adopt a strange method for so doing, by digging a ship canal two miles westward, and attempting to establish a sea-entrance near Winchelsea. On this project the transit-tolls were expended till the year 1764, and after some contest in Parliament, further continued by an Act passed in the year 1777. But the works hitherto done being quite useless, Mr. Smeaton was con-

The expense of executing the Nene Outfall has been about £.200,000; about 1,500 acres of land have been secured from the sea by the con-

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sulted in 1763, and he recommended a further effort by *entirely* stopping the entrance of the old harbour, with a view of increasing the power of scouring the ship-channel, not at all reprobating a sea-sluice erected by the Commissioners of Sewers (that is, by the land-owners) across the river Rother, at some distance above the town of Rye, whereby the influx of tide was precluded, and the harbour had been ruined for want of its natural back-water.

About twenty years since, this sluice fell to decay, and was destroyed by a river-flood, when the inhabitants of Rye opposed its restoration, the absence of the impediment having, in one year, given three feet additional depth in the harbour channel, and at the town-quay. But the wealthy proprietors of the levels effectually resisted the wish of the inhabitants, and one of them in Parliament said it was a serious thing to interfere with landed property worth £.1,400,000. This assertion seems to infer a net rental of £.45,000 a year, or about 15,000 acres of land which had formerly been covered with water at spring-tides; but this may be deemed an exaggeration suited to the occasion, and more truly descriptive of the entire levels than of the more recent encroachments by which the harbour of Rye was finally destroyed.

The sequel of the Rye Harbour experiment is very instructive. The piers and wharf and sluices had been so completely silted up, that the masonry was dug out, and the stones sold, some years before the above question was discussed in Parliament.

A similar transit-toll created the Ramsgate basin, which, as a harbour of refuge, is but of questionable benefit. Mr. Smeaton was there successful in establishing an effectual back-water for scouring away the loose sand brought in by every tide, and the essential part of the work was finished under his direction in the year 1791; but the tolls were continued by a new Act, and have been levied ever since to the amount of half a million of money; more than £.9,000 a year has been expended in harbour masonry, and nearly £.4,000 a year in the collection and general management of the tax thus levied on commerce; a striking example of the injustice consequent on transit-tolls, which are not easily removed when once established.—At Dover (between the before-mentioned towns) the attempts to keep open the harbour entrance had been founded on inveterate error, when Mr. Telford (shortly before his death) was employed there, and proposed a plan for improvement; but with what result is yet undecided.

Finally, we must confess, as before said, from these and similar instances, that human knowledge, especially knowledge depending on experience of facts and results which rarely occur, is slowly progressive, and therefore that civil engineers are not infallible. The state of their acquirements, in the year 1806, as to the effect of embankment and back-water, may be inferred from the vague, inconsistent and unsatisfactory evidence of those who appeared before a House of Commons' committee, then appointed to investigate the probable effect of the embankment of *Catwater* (a branch of Plymouth Harbour).

To return to Wisbeach:—Mr. Telford had improvement in view (in certain prospect, he might say), and such as must be highly beneficial to that town; but improvement involves alteration; and the innumerable instances of well-intended labour in the fens failing of its desired effect, added to the many instances of water diverted from its former course, to the injury of individuals, with or without benefit to the general interests of the fens, cannot but have sunk deeply into the minds of near spectators, whose property and

current embankment across the formerly dangerous Washway; a great portion of this land is now (1833) under cultivation; about 4,000 acres

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welfare were hazarded by every such experiment; and referring to Mr. Telford's historical narrative of fen-drainage, the inhabitants of Wisbeach might allege, 'That from the time of 'Queen Elizabeth it had been attempted continually, and in various modes of disputable 'efficacy; that Mr. Telford has unquestionably been successful in opening the Nene 'Outfall, by which we acknowledge that an improved access from and to the sea has been 'obtained, and that the commerce of Wisbeach has proportionally increased; but not 'without drawback in the endangered bridge, and the expense of repairing or securing 'our warehouses and granaries and wharf-walls, continually undercut by the reflux of the 'river-tide. Hence the balance of benefit becomes somewhat doubtful; and the improve-'ment of the river, in making it navigable to Peterborough, might possibly transfer the 'existing trade of Wisbeach to that place; inasmuch as commerce often takes her station 'at the highest navigable limit, as at London, Newcastle-on-Tyne, Bristol and Glasgow. 'All property at Wisbeach might thus be depreciated by the prosperity of Peterborough; 'and although the security of the fens above Wisbeach would be extensively beneficial to 'the proprietors,—Who will undertake to indemnify us against detriment, if such a plan as 'Mr. Telford's, or even the modified proposal of Sir John Rennie, were carried into effect? 'Are we not bound, in justice to ourselves and our family property, to resist such inno-'vations to the uttermost, unless and until some satisfactory compromise can be adjusted, 'and a distinct indemnity, conformably thereto, secured to us by the same law which 'endangers our property?'

This plea opens a question which has never been placed before the public so distinctly as its importance deserves. To understand it, we must consider with attention the extent of national benefit which has accrued and still accrues, from the recognized absolute power of British legislation, in binding the mutual arrangement of all joint-stock companies among the proprietors themselves, and rendering them unassailable from without; still more in granting them power to interfere with private property, and even to take forcible possession of it, sufficiently for their purpose. To prove that the grant of such power is one of the most beneficial functions of the British Parliament, it is only necessary to ask oneself, What would England be now, if suddenly deprived of all the benefits derived from such exertion of judicious despotism? Intercourse by turnpike-roads and railways, by the improvement of navigable rivers, and by canals, would be foreclosed, and the most improved region upon earth relapse into comparative barbarism. Nor let it be supposed by civil engineers, that vulgar military despotism could effect the like; their profession owes its existence as a profession, to the steady and unimpeached power of Parliament beneficially exercised and fully in use, during the last hundred years of English history. Elsewhere a privileged joint-stock company may be taxed, if prosperous,—or supplanted by the pecuniary offer of a rival association. Elsewhere the great lords, and all other landed proprietors, would rise with one consent against their sovereign, if he ventured to say to the Lord Bojar of Wisbeach, 'It is my pleasure that your property be sacrificed for the benefit of others; and I authorize them to take possession of it accordingly.'

Thus it seems to follow from the social, almost sacred, establishment of the rights of private property, that it ought not to be depreciated, much less be made liable to forcible though legal seizure, without ample indemnification, even to the amount of twice its value,

more will be gained in a few years, in consequence of the diversion of the channel from the ancient estuary; but this acquisition is as nothing compared to the benefit of a natural drainage for the entire North Level, South Holland, and the contiguous districts.*

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or of the apprehended damage; and on this principle juries seem often to decide. But in cases which affect the welfare of a town, of a whole community, where also the damage is future, and of uncertain amount, not only the extent, but the manner of ascertaining and apportioning the contingent indemnity, ought to be left to the discretion of those whose property is endangered; a discretion which will never be unreasonably, certainly not outrageously, enforced, because it will always be conscious of its moral limit and imbecility, if opposed to public opinion. Under such modification, the improvement of the river Nene in its passage through Wisbeach, or near Wisbeach, is by no means unattainable, the inhabitants having previously to consider among themselves the mode and extent of indemnity for possible damage, should it occur.

But the supposed plea of the inhabitants of Wisbeach must not be allowed to pass without attempt at answer, on behalf of the improvement of the navigation of the river Nene to Peterborough. The town of Great Yarmouth, in Norfolk, relies for its prosperity on the transhipment of all mercantile commodities to and from Norwich; and Wisbeach cannot fail to become another Yarmouth, whenever the population of the fens shall increase from the effects of improved drainage, and when Peterborough, like Norwich, shall become a central station of inland traffic (extending perhaps to Leicester), with equal advantage to the prosperity of Wisbeach. For it is not likely that large sea-borne shipping will ever be enabled to penetrate above Wisbeach, and even prohibition against such a contingency might not be an unreasonable safeguard or compromise, were the projected improvement of the river Nene navigation to be carried *fully* into effect, with the approbation of all parties.

Still further might be urged, on behalf of the good people of Wisbeach, the recent example afforded at Lynn, where the enlargement of the Eau-brink Cut has unintentionally and unexpectedly directed the outfall current aside from an extensive range of quays, which are already become inaccessible to shipping; and the attempt to prevent further deviation, by timber jettees on the opposite side of the river, is but a weak expedient opposed to the force of so vast a body of water as is accumulated by a tide which rises from 10 to 15 feet perpendicular, and its downward reflux sometimes prolonged by the discharge of inland floods. Still more forcible is the plea for contingent indemnity at Wisbeach, inasmuch as no such injury was apprehended at Lynn by the Navigation Commissioners, who on the contrary feared that the quays, and even the town of Lynn itself, might be gradually swept away, should the current have taken an opposite direction.

Thus hazardous to private property are fen improvements; and it is not improbable when Denver Sluice near Downham shall be removed, and the tide flows up to Ely, that the old river channel, towards the lower termination of the Eau-brink Cut, must be resumed, if means can be devised for regulating the quantity of water discharged by it and by the Eau-brink Cut, so as to obtain a power of regulating the direction of the outfall current, as affecting the important interests of the town of Lynn Regis.

* In the Appendix (G.) will be found a full account of the effect produced by this outfall, by a friend who accompanied me in August 1830, containing his very judicious observations upon drainage generally.

NORTH LEVEL DRAINAGE.

The formerly impeded outfall of the river Nene, at Sutton Washway, choking and impounding the water upon the sill of Gunthorpe Sluice (which was eleven feet three inches above low-water at Crab-hole), it was but too often felt that even with the aid of windmills and a steam-engine, every district of the North Level was in imminent danger of sustaining serious damage. In my Report to the North Level commissioners of the 18th November 1828, it was stated that, in consequence of the recent improvement of the Nene Outfall, Gunthorpe Sluice might be lowered about eight feet, and thereby a natural drainage be obtained for all the lands between Morton's Leam and the river Welland;—as is proved by the following extract from that Report: 'Having considered 'the plan and levels taken by Messrs. Swansborough and Pear, I have 'to state the following results: at Crab-hole' (a well-known anchorage in the Wash, six miles distant from the Sutton Washway, or rather from the present causeway and bridge near Long Sutton, by which that dangerous passage has recently been superseded), 'low-water has been 'determined, by repeated levelling, to be eleven feet three inches below 'the sill of the Lutton-Leam Sluice, and the acclivity of the new river-'bed being at the rate of four inches in a mile, it rises 28 inches in 'the distance from Crab-hole to Gunthorpe Sluice, being seven miles; 'from Gunthorpe Sluice to Clows Cross the distance upwards is eight 'miles and a quarter, so that the rise in the bed of the intended drain, 'at four inches per mile, will be two feet nine inches, making from 'Crab-hole (in about 15 miles) five feet one inch. The surface of the 'fen land at Clows Cross is nearly 14 feet above the before-mentioned 'outfall (assumed to be at Crab-hole), or about eight feet above the 'proposed sill of the sluice at Clows Cross; so that, admitting the 'depth of water on the sill to be three feet (found by experience to be

‘ sufficient for the drainage), the surface of the land remains five feet ‘ above that of the water.

‘ The surface of the land in Tyd and Newton Fen is 10 feet above ‘ low-water at the outfall, and distant from it 12 miles, in which the rise ‘ will be four feet, and allowing three feet water in the drain, the surface ‘ of the ground remains three feet above it. The land at Knar-Cross ‘ is 21 miles from Crab-hole, and 13 feet above low-water; and being ‘ distant six miles from Clows Cross, an acclivity of three inches in ‘ a mile upwards from thence, with an allowance of three feet of water ‘ on the sill of the sluice at Clows Cross, will leave the water surface ‘ at Knar-Cross two feet six inches below the land.

‘ The land in the North Fen is nine feet six inches above the intended ‘ sill at Clows Cross; and allowing three feet of water on the sill, and ‘ a rise of three inches per mile above Clows Cross, at the distance of ‘ four miles, the surface of the land will be five feet six inches above ‘ the water in the drain adjoining.

‘ In Low-Borough Fen the surface of the land is 14 feet above low- ‘ water, or eight feet above the sill at Clows Cross, from which it is ‘ distant eight miles; and allowing an acclivity of three inches per ‘ mile, as before, with three feet of water on the sill, the surface of the ‘ land will be three feet above the water in the adjoining drain.

‘ The sills of the Outfall sluice and of Clows Cross sluice are laid twelve ‘ inches above the rise, estimated at four inches per mile; therefore one ‘ foot is lost in these calculations from what would otherwise be the ‘ height of the land surface above water in the drains. The land-freshes, ‘ from observation during the former state of the river channel, adjacent

'to the site of the sluice, rise only three feet upon the Old Gunthorpe 'Sluice, and the bed of the river is about the same level as the sluice. 'When freshes in the river run three feet in depth, there would only be 'two feet on the new sill; and as the water in the river is calculated at 'three feet, there will be one foot of head to discharge the interior 'waters from the drains; but it must be considered that the actual 'outfall is obstructed by the tidal waters during many hours in every 'tide, and from this cause, admitting the discharge of the river between 'Gunthorpe Sluice and Crab-hole in the Wash in great freshes to require 'a fall of eight inches in a mile, or double the inclination of its bed, then 'an additional head of water to the amount of two feet four inches will 'be required in the course of the drain, and one foot four inches imme-'diately above the sluice, to discharge the interior waters into the river; 'but even in this extreme case, the water in the drain will be eight inches 'below the surface of the lowest land in Tyd and Newton Fen, and 'proportionally more than eight inches in every other situation which 'has been described.

'It remains only to specify the dimensions assignable to the several 'drains. From Gunthorpe Sluice to Clows Cross, the bottom width of 'the new drain is 40 feet (with sufficient side-slopes), gradually dimi-'nishing in its passage upwards to 30 feet, at Clows Cross; thus far the 'acclivity being (as already stated) four inches in a mile. From Clows 'Cross to the Black-horse Sluice, the bottom width of the new South 'Eau is 30 feet, gradually diminishing in its passage upwards to 24 feet, 'with side-slopes of two to one, and an acclivity diminishing to three 'inches in a mile. The New Wryde drain, from Clows Cross to its 'junction with the Old Wryde stream, has 30 feet width of bottom, 'diminishing in its passage upwards to 24 feet, with side-slopes of two 'to one, and an acclivity of three inches in a mile. The Drain, from

'Old Wryde to Knar-Cross, has a 24 feet wide bottom, diminishing 'upwards to 20, with an acclivity of three inches in a mile.'*

From the foregoing statement, it was evident that the whole of the North Level (including Portsand) might obtain a natural drainage, whereby the expense and uncertain effect of 30 windmills would be obviated. In 1830 an Act for this drainage was obtained, and the excavations immediately commenced. Power had previously been obtained to construct an outfall sluice, which was successfully completed under the immediate superintendence of Messrs. Swansborough and Pear, the last a veteran director of fen drainage.

I cannot, I confess, without some self-complacency, reflect upon the success of my drainage operations in the North Level, having thus recalled (as it were) into use the aid of a natural outfall, which had not only been neglected or forgotten, but even systematically impeded by a labyrinth of drains and sluices, the expense of maintaining which had been such as to persuade the Fen proprietors to estimate these subordinate inland expedients as essentials, instead of adjuncts to the better principle, of admitting freely the scouring force of the influx and reflux of the tide.

In conclusion, I cannot but repeat, that the complete success of this valuable improvement is chiefly attributable to the enlightened and

* It is quite vexatious throughout this detail, to encounter perpetually the words *Acclivity* and *Declivity*, which (like the fabulous shield, gilt on one side, silvered on the other) change places as we look up or down a river; and the word *Inclination* (by which Mr. Telford sometimes seeks to combine the two former words) has other meanings, which prevent its convenient application to this purpose. Dropping the first syllables, *Ac* and *De*, the word becomes *Clivity*, fairly derived from the same Latin word (*Clivus*).

liberal conduct of the Duke of Bedford, and his agents, Mr. Tycho Wing and Mr. William Adam, who had the sole management.*

OF HARBOURS.

Connected with the improvement of river outfalls, are such improvements of harbours in the estuaries of rivers as have been made from plans furnished by me, and executed under my directions. Of these, two of considerable importance are on the east coast of Scotland; one at the city of Aberdeen, the other at the town of Dundee; and as I was first employed at Aberdeen, I shall begin with that harbour accordingly.

ABERDEEN HARBOUR.

[*See* Plate 35.]

The city of Aberdeen is situated on a projecting part of the east coast of Scotland, in 59° 9′ north latitude, and 2° 8′ west longitude, and is 106 miles from Edinburgh. It is the principal town of an extensive county, and is, in fact, two conjoint towns, the Old and the New. The former was long considered the principal town in the north of Scotland, being frequently the seat of royalty, and not seldom plundered by foreign enemies and domestic factions. Its earliest charter

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The want of such obvious introduction of the word *Clivity* has produced in railroad discussions the newly-invented word *Gradient,* which ought to be superseded by the word *Clivity,* and dismissed from the vocabulary of civil engineers. In road-making a similar difficulty, and one more easily removed, occurs, in saying *to* or *from* any place; the proper phrase is, "the road *between* London and Croydon."

* In the Appendix (G.) will be found a valuable memoir, and other papers, furnished by Mr. Tycho Wing, who, residing at Thorney Abbey, in the middle of the North Level, had full opportunity of witnessing the progress and effect of practical operations.

was granted by David I., who removed the episcopal seat from Mortlach in Moray to this place. In 1336, Edward III., on his return from Inverness, cruelly treated the inhabitants, and laid the town in ashes.

On this occasion, what is called the New Town originated; and from the situation selected, it is probable that convenient access to the sea was then considered to be of importance, for instead of rebuilding the Old Town, which is situated on elevated ground on the south bank of the river Don, the New Town stands on the north side of the river Dee, where it falls into the south corner of a bay, protected by the promontory of Girdleness. In this place a city has arisen, which, including the Old Town, contains 58,000 industrious inhabitants, with two well-endowed Colleges or Universities, in which there are usually 400 students.

The whole property of the harbour, with the dues arising from the shipping, is, by charter, vested in the magistrates and town council. This harbour formerly consisted merely of the mouth of the river Dee, which admitted the tide to flow upwards about two miles over very flat ground, and by thus spreading wide, its current did not acquire force enough to carry out to sea the alluvial matter brought down from above, sufficiently to carry it round the point of Girdleness; so that, being checked by the external tide, the mud, sand and stones were deposited, and formed a bar, which formerly admitted only small vessels to the warehouses, although these were built as near to the river as was practicable. Towards the middle of the last century, this bar was felt to be a great obstacle to the prosperity of the port; and the magistrates being desirous to improve the harbour, applied to Mr. John Smeaton, the most eminent engineer of that day. The commerce of the place did not then justify any thing beyond a tide-harbour; and Mr. Smeaton's

views were therefore limited to that object. He found the river meandering over an irregular space, upwards of 500 yards in breadth, and he applied the only practicable remedy, by confining the channel as much as the limited amount of expenditure permitted, and directing the land-floods so as to act upon and diminish the bar; for which purpose he founded the north pier, extending 700 feet eastward from ordinary high-water mark, and about 500 feet farther, with a northern slant, to turn the current into a proper direction. This pier, besides forming a proper channel, was a barrier opposed to the sands previously deposited in the river by the flood-tide. Opposite to this pier, on the south side of the river, was constructed another pier, or rather a breast-wall, about half the length of the pier; these, with two short jettees and a small basin, comprehended Mr. Smeaton's plan for improving Aberdeen Harbour, all which was carried into effect under an Act obtained in the year 1773.

But the commerce of the port continuing to increase, in the year 1797 further improvements were urgently demanded, and the magistrates, ever anxious to promote the increasing prosperity of the city, called in Mr. John Rennie, then engaged in forming plans for accommodation at the port of Leith, on the principle of floating-docks; and that engineer, who deservedly ranked high in his profession, furnished a plan for improving Aberdeen Harbour, which he proposed to accomplish by abandoning the river, and constructing floating-docks upon the sandy flats called Foot-Dee. This was certainly in exact conformity to the prevailing mode adopted in the Thames, at Leith, and other places; but fortunately for the future improvement of the Harbour, the proposed situation of docks, being at a distance from the existing mercantile establishments, was considered as unsuitable to Aberdeen.

During the following five years nothing was done. In 1801, I was employed by Government in making a general survey of the coasts of Scotland; and when at Aberdeen, the magistrates drew my attention to the state of the harbour, and requested a report as to what I considered most advisable for the entrance and accommodation of a larger class of ships than could then be admitted.

After having examined the state of the river opposite the town, its outfall at Girdleness, the nature of the land-floods, and of the tides, and having caused the quality of the ground to be ascertained by borings, I made a plan, and gave in a General Report on the 9th April 1802. As this Report states distinctly my original idea, and as an Act was obtained in 1810 on its principles, and which has ever since, with some slight variations, been acted upon, I shall here insert the substance of my Report. The objects I had in view were,—viz.

1st. To provide, at the least possible expense, the greatest extent of wharfage and floating-docks.

2d. To avoid injuring the fisheries in the river, or occupying the building ground at Foot-Dee, on its north side.

3d. To acquire new ground for ship-building and timber-yards, on the mud banks called the Links, with proper communications to and from the city.

4th. To place locks and graving-docks upon ground which might afford the best foundations, and be convenient for admitting vessels.

5th. To provide the means of scouring the docks, and therein causing the flux and reflux of the tide, as well as the land-floods, to act most effectually on the existing bar, and prevent future accumulation there, so as to obtain and preserve four

feet additional depth of water, and thereby admit large vessels at neap-tides.

6th. To form a communication between the Aberdeenshire Canal and the new harbour.

'Having these objects in view, the leading features for the execution 'of my plan were to place a lock in the channel, which passed along 'the face of the then quays, on a spot where strong red clay had been 'found by the trial borings, and to make excavations of a sufficient 'width and depth for floating-docks alongside the quays, upwards to 'Denburn, applying the excavated earth to raise the surface, and form 'a protecting bank along the north side of the river, of a sufficient 'height to divert the flood-waters from flowing over the space which 'was to be converted into a floating-dock, protected and regulated by 'flood-gates, when necessary; a solid mound was also to be formed, so 'as to divide the whole length into two basins, with a ready communi-'cation between the city and the newly-acquired ground on the Links; 'through this mound a passage to admit vessels to the upper part of 'the harbour, with gates to keep up the water occasionally, when let 'out of the dock below the mound; the former quay to be rebuilt, 'widened, and the new foundations laid at a proper depth; and I 'proposed that on the Inches, the surface being previously raised, a 'space of about 40 acres should be appropriated to ship-building, 'leaving the Foot-Dee for commercial purposes; while, by means of 'the river and Denburn, not only might the docks be effectually scoured, 'but the whole body of water be thrown upon the bar and entrance, in 'aid of the current of the river Dee. By these improvements the river 'fishery could not be in the least injured; nothing more than raising 'the north bank, and cutting a small portion of ground at Point-Law, 'being intended as to the main stream.

'For the purpose of obtaining and preserving a greater depth of 'water on the bar, and at the entrance of the harbour, it was necessary 'to extend the north and south piers very considerably, by doing which 'I expected that at least four feet more water would be obtained; and 'the foundation of Mr. Smeaton's piers not having been laid to the 'depth now required, they were now to be secured, and the whole 'entrance protected by an extensive breakwater.'

Although the magistrates were satisfied that this plan was suitable in all respects to the wants of the port, they found difficulties as to arranging the new harbour dues; so that it was not until the year 1810 that an Act was obtained, and then not without opposition from a party desirous of taking the management from the magistrates and council. Several years previous to the Act being obtained, the magistrates had applied to me to recommend an able, experienced person to superintend whatsoever should be finally resolved on, and for that purpose, in the year 1809, I selected Mr. John Gibb, who had for several years been practically employed in canal and harbour works. By means of his personal knowledge, acquired by residence, I was furnished with correct information as to tides, materials, and other necessary data, so that, when the Act was passed, the working drawings and specifications had been already prepared, and Mr. Gibb, with unremitting attention, superintended every operation connected with these difficult works, in which he has distinguished himself by remarkable ingenuity and perseverance. I shall here insert his detailed narrative of the progress of the works from their commencement, a narrative prepared at my request, because, as its accuracy may be relied on, it cannot but be of service to practical engineers engaged in similar works.

Here follows Mr. Gibb's Narrative (illustrated by Plates 36 and 37):

" The improvement of Aberdeen Harbour commenced with the restoration of Mr. Smeaton's south pier-head, which had been destroyed in the winter of 1807. The foundation of the improved pier was laid in October 1809, and the superstructure completed in the following year; it consists entirely of cut granite, and is finished with a slope of five horizontal to one perpendicular.—[*See* Appendix (H.)]

" In 1810, the magistrates, as trustees, obtained an Act for carrying into effect Mr. Telford's plan; and as the extension of the north pier appeared the most difficult and dangerous part of it, the trustees, after receiving the necessary working plans and specifications, made preparations for this extension by laying down a railway, procuring the necessary machinery, and ascertaining the best stone quarries; and in the spring of 1811 the entire 300 feet extension was completed.

" The beneficial effect of this extension was so apparent, that a very general opinion was expressed that it should be carried still farther, especially as the portion already finished had been executed considerably under the estimated expense; and Mr. Telford, who inspected the work in December 1811, after approving of the manner in which the resident engineer had conducted it, found that it would be of great importance, not only as carrying the pier into deeper water, but to enable vessels to clear the Girdleness point. The trustees accordingly resolved to extend the pier 780 feet beyond Mr. Smeaton's head, and in pursuing the plan of extension, as formerly proposed, to construct a breakwater from the south shore.

" Accordingly, during the winter of 1811 and the spring of 1812, preparations were made, and during that year the whole length, except

the outer head, was accomplished. In the following year, 1813, Mr. Telford again visited the works, and on the 17th December, the extension of the pier performed under his direction measured 865 feet, which had been accomplished in three seasons, and in open exposure to the German Ocean. In the following tempestuous winter, the outer head was considerably injured, so that it became necessary to alter its formation into a very flat slope of about five to one all round the head, in which form it now stands. The bottom under the foundation is nothing better than loose sand and gravel, constantly thrown up by the sea on that stormy coast, so it was necessary to consolidate the work under low water, by dropping large stones from lighters, and filling the interstices with smaller, until it was brought within about a foot of the level of low water, when the ashler work was commenced; but in place of laying the stones horizontally on their beds, each course was laid at about an angle of 45 degrees, to within about 18 inches of the top, when a level coping was added. This mode of building enabled the work to be carried on expeditiously, and rendered it while in progress less liable to temporary damage, likewise affording three points of bearing; for while the ashler walling was carrying up on both sides, the middle or body of the pier was carried up at the same time by a careful backing throughout of large rubble-stone, to within 18 inches of the top, when the whole was covered with granite coping and paving 18 inches deep, with a cut granite parapet wall on the north side of the whole length of the pier, thus protected for the convenience of those who might have occasion to frequent it.

"The outside of this pier is composed of roughly-dressed granite ashler, and headers from three to six feet long,* with corresponding

* A *header* is a stone of which the end appears in view, as does the side of a *binder* or *stretcher*.

binders to suit the headers, and within is a core or hearting of large rubble-stone of that description called *Gneiss*, packed with spauls of a suitable size.*

"In procuring the granite ashler, the trustees generally advertised the price they would give for the stones delivered at their depôt, in the interior of the harbour, by which means every quarry, of which there are several within five miles of the harbour, some within a mile and a half, could deliver whatever it could produce, so that thus the trustees were enabled to command an immense supply. The community or corporation of Aberdeen possess a considerable property along the shore to the south of the harbour, where there is an extensive range of gneiss rocks, called by the masons *Heathens*, because they cannot be dressed into a regular shape. On this shore the trustees opened quarries, and contracted with persons to deliver by the ton such stones as required carting; but as it became indispensable to protect the pier-head with stones of very large dimensions, which could not be conveyed by land, about 200 such stones, weighing from 5 to 30 tons, were procured on the south shore, where stones of the largest class were slung by powerful machinery between the bows of two lighters, each lighter having a counterweight towards the stern; and the smaller class stones were suspended from the bow of one lighter, with a counterweight at the stern, and thus floated to the pier-head, where these vast stones were deposited in their proper places. This was found to be a very arduous task, but by attention and care it was accomplished without any accident.

"To facilitate the operations, a railway was laid down from the lower old wharf, along Mr. Smeaton's old pier, at the extremity of which a

* The interstices filled with small irregular stones.

powerful double crane was stationed, which being made to move on rollers, the railway and crane were advanced, as the work proceeded. To each side of the crane and railway were adapted proper passing places, so that the waggons laden with stones were brought directly under either of the cranes; but as it would have been impossible to convey and deposit by this mode, in a limited space of time, one-tenth part of the stone required, six strong lighters of 40 tons each were built, and on each of these was mounted a powerful crane, by which the stones were taken on board, and by using these lighters whenever the sea was tolerably smooth, the foundation and lower part of the work was generally kept considerably in advance of the upper part, and the whole proceeded with a regularity and despatch seldom experienced in work depending on the state of the tide.

" As already mentioned, the great length to which it was considered advisable to carry out the north pier, rendered indispensable a corresponding extension of the pier on the south side of the entrance, and in place of making this parallel to the north pier, it was deemed proper to extend a solid breakwater from the south shore in a north-east direction, so as to leave a space of about 250 feet as an entrance, leaving a sloping beach within the breakwater, to give scope for the surge to spend itself so freely as to prevent agitation in the interior of the harbour. This breakwater, by narrowing the entrance, also deepened the channel; wherefore, in 1812, Mr. Telford gave directions that from the gneiss quarries on the south side, a railway should be laid to the proposed breakwater. The length of the breakwater is about 800 feet, and it is constructed of large rubble-stones as they came from the quarry, excepting a portion of the head, which is formed, in the before-mentioned sloping manner, with roughly-dressed ashler; the sectional figure is formed with an outward slope of about 45 degrees,

where most exposed to the ocean, and about half that slope on the inside; it is raised five or six feet above the level of high water (in ordinary spring-tides), and strongly pitched on the top with large blocks of roughly-hammered stone; a parapet was unnecessary, but a considerable shoeing of rubble-stone surrounds and protects this head of the breakwater.

" By the completion of the north pier and of this breakwater, a permanent depth of five to six feet has been gained, so that although the expense has been great, it cannot be put in comparison with the advantages thus obtained by the port of Aberdeen.

" We now proceed to other operations in the interior of the harbour, where the tide rising from 10 to 12 feet in spring-tides only, and from seven to nine at neaps, vessels of any considerable draught of water could not get up to the old quays without being first lightened by means of barges (lighters), so that an extensive deepening in the interior was very desirable; the trustees, therefore, with the advice of their engineer, shortly after passing the Act of 1810, procured a dredging machine, worked by a steam-engine, which having been in use since 1811, an additional depth of from three to four feet on an average has been obtained through the whole extent of the interior (that is, about a mile), so that vessels of every description get up to the quay, and lighterage is become unnecessary.

" In a situation so much exposed as that of the north pier and breakwater, it was expected that the workmen would be frequently interrupted; therefore, Mr. Telford, with a view of employing them when driven from the pier, directed that a portion of the wharf-wall, which was to form a part of one side of the wet dock, and likewise that the capstern

towers, which were to form the extremity of the new cut, should be commenced; and the trustees accordingly, between 1811 and 1815, constructed 900 feet in length of a new wharf, built the before-mentioned towers, and effected part of the excavation of the new river channel, likewise a great portion of the embankment, which will form the south side of the wet dock.

"At this period, the funds being considerably exhausted, the trustees deemed it advisable to suspend operations, and from 1816 (when Mr. Gibb relinquished the situation of resident engineer) until the latter end of 1829, very little work was done, excepting dredging. But in 1828, the trustees having resolved to apply for a new Act repealing former Acts, Mr. Telford was requested to reconsider his former plans, a part of which still remained to be performed, and the chief alteration proposed by him was to remove the tide-lock a little higher up the harbour, in order to afford a larger entrance basin, also the demolition of several old jetties, to increase the tide basin, and to construct a new wharf of about 600 feet, in order to accommodate the berthage of vessels bound to other ports, but which might enter the harbour as a place of safety, in stormy weather, without discharging their cargoes; room was also thus obtained for constructing Morton's inclined planes, which had by this time been found useful for repairing ships.*

"The trustees accordingly, in 1829, obtained an Act for carrying the improved plan into effect, and Mr. Gibb, with his son Alexander, as joint resident engineers, were appointed to superintend the works as

*. The particulars of Morton's meritorious invention, for the examination and repair of a ship's bottom without the aid of a graving dock, may be seen in the evidence adduced before a House of Commons Committee, printed 13 April 1832.—[*See* Appendix (H.)]

before; and as the dredging machine was worn out, a new one, with a corresponding number of discharging punts, was constructed.

"The trustees also, during the year 1830, constructed 1,350 feet of new wharf, forming a still farther extension of one side of the wet dock, and enlarged an embankment, so as to make the whole breadth of the wharf 100 feet; the embankment of the Inches was also enlarged, so as to form the southern side of the dock; the trustees likewise constructed 600 feet of wharf below, in order to form one side of the tide basin.

"A considerable portion of the excavation for the new channel of the river Dee has been completed, and the new wall built, which is to form its southern boundary; the foundations of the new wharfing are all placed on a platform of timber (bearing piles under), with a row of sheet piling in front; the outside face of the other wharfs is wholly built of granite ashler, backed with rough hammer-dressed masonry laid in lime mortar (from Lord Elgin's kilns), which sets in water, and the outside joints are pointed with Parker's cement.*

"The general bottom of the entire harbour is composed of sand and gravel, so that all these buildings required artificial foundations, effected by means of coffer-dams, and below the level of low water, chain pumps were necessary.

"In the years 1831 and 1832, the right bank of the new channel was completed, also the spill (spoil) water bank, the former 1,630, and the

* Parker invented the cement, well named by him *Roman Cement,* at the close of the last century; but the discovery was not at first productive, and, having sold his patent to Mr. Samuel Wyatt, he emigrated to America, and soon died there.

latter 4,107 feet in length, with proper slopes and all other necessary precautions to resist the impetuosity of land floods, and accommodate the fisheries; the wharfage has been extended to the upper parts of the town, and a turn-bridge constructed so as to form a connexion with the new ground on the Links.

"The expense of the works, which have been constructed under Mr. Telford's direction, was as follows:

	£.
Extending the piers and breakwater - - - - - - - -	81,955
Dredging the inner harbour - - - - - - - - - -	17,999
Constructing new wharfs and common sewer - - - - - - -	39,738
Forming a new channel for the river, including capstern towers and jetty, also constructing a bulwark and embankment - - - - -	15,398
Making a communication bridge to the Inches - - - - - -	5,500
	£. 160,590

"Aberdeen, as a maritime city, may be classed as the third in Scotland; its manufacturers, merchants and ship-owners are a spirited and enterprising people, who trade largely with the West Indies, North America, the Continent and Mediterranean, and they have also a considerable share in the Northern Whale Fishery; the shipping of Aberdeen, in point of appearance and durability, is not any where surpassed, and several powerful and splendid steam-packets ply between this port and London and Leith.

"The several manufactories of wool, cotton, flax, hemp and iron are carried on to a great extent, and to the greatest perfection. The staple articles of import are pine timber (European and North American), also oak timber from England for ship-building, raw wool, cotton, flax, hemp, iron, bark, coals, lime, salt, tallow, ashes, leather, seeds, glass, china and stone-ware, ironmongery, &c. The articles of export consist of woollen manufactured goods, also of cotton, hemp and flax, the

thread manufactory particularly being held in high estimation; granite stone is exported superior to any other; and, in great abundance, fresh and pickled salmon; of late, barley, oats, butter, pork and eggs have become articles of export to the amount of £. 130,000 annually received for these agricultural products."

Mr. Gibb has thus, in a distinct manner, detailed the progress of the harbour works up to the end of 1832, and states the probability of my plan being completed, which will render Aberdeen not only a commodious port for commercial transactions, but the outer harbour will become a safe shelter on that dangerous coast.

The following Statement will demonstrate the rapid progress of the trade and commerce of Aberdeen :—

Tonnage of Vessels entering Inwards and clearing Outwards :—

	Inwards.	Outwards.
One year to July 1800	56,404	43,129
July 1810	81,299	57,914
July 1818	108,199	85,702
July 1829	157,457	121,420
July 1836	202,043	

Amount of Harbour and Shore Dues :—

	£.
One year to July 1810	5,600
July 1815	7,100
July 1820	7,700
July 1825	9,900
July 1830	10,700
July 1831	12,595
July 1836	13,163

Registered Tonnage in the Port of Aberdeen (including Banff till the year 1800 inclusive):—

	Vessels.	Tons.
1760	98	5,020
1770	143	8,110
1780	128	6,613
1790	179	13,618
1800	184	15,571
1810	201	20,266
1820	—	45,031
1828	338	45,855

Mr. Gibb's Narrative continued:— *

"With regard to the improvements of the harbour, the following are the principal works which have been executed since 1830, agreeably to the Act of Parliament obtained in 1829:—

"1. A new channel for the river Dee, and a spill-water channel, have been formed, by which means the river is now kept entirely out of the harbour.

"2. A cast-iron turn-bridge has been constructed at the foot of Marischal-street, across the harbour to the ground on the south side, called the *Inches*, which, by means of embanking, has been enlarged to a very great extent.

"3. A quay-wall has been built along the whole of the north-eastern side of the harbour, being a length of 3,200 feet, exclusive of Waterloo

* The reader is requested to understand, that this latter part of Mr. Gibb's narrative (which is dated September 1837) has been obtained from him since the death of Mr. Telford; but for the sake of continuity appears in the text as a sequel of the former part; the concluding paragraph by Mr. Telford is generally applicable.

Quay, which was previously built, and is 920 feet in length. This is a spacious quay of 100 feet in breadth, which has been already paved the whole length, with the exception of a short distance at the upper end, not much occupied.

"4. A quay-wall of 1,200 feet in length has been built on the Inches, or acquired land on the south side of the harbour, to which the lime trade has been removed, and buildings for its accommodation have been erected by the harbour trustees. There being no lime in the county of Aberdeen but one small work 40 miles north, the trade in lime here is very considerable, as is also that in coal, of which Aberdeenshire is destitute.

"The foregoing wharfs, with the addition of what is called Pocra Jetty, and the lower jetty (which give wharfage of 370 feet),—and the lower basin of 600 feet,—all taken together, now give quay berthage to this harbour of no less than 6,290 feet, or one mile and 336 yards; being superior, therefore, in this respect to any dry harbour in the kingdom; and all have been executed by following out the original plans furnished by the late Mr. Telford.

"5. The trustees have constructed a building slip, according to the patent of Mr. Morton, capable of receiving the largest class of steamers for the purpose of repair.

"The harbour has also been deepened by means of dredging, so as to admit the largest class of shipping up to the foot of Marischal-street, or two-thirds up the harbour, affording thereby great facility to the trading community.

"There are now three steam-ships, of the largest class in the trade, between Aberdeen and London, and three in the trade to Leith; two of the latter make a trip, one to Inverness and one to Orkney, every week during the summer season, calling at the intermediate ports."

Aberdeen is one of the most striking instances in Great Britain of the effect of persevering industry; situate in a bleak, barren region, where a mass of granite branches from the inland mountains to the sea-coast, and there terminates in a bold, rude promontory, the country on each side of the river Dee was originally covered with innumerable blocks of the same material, and the mouth of the river scarcely accessible to small fishing-boats. One can scarcely conceive what could have induced man, at first, to have settled in a place where could be little prospect of procuring even necessary sustenance. It is possible to conjecture that a Norwegian tribe, under one of their sea-kings, may, after in vain attempting a settlement on the southern parts of Britain, have fixed their abode in a climate, perhaps one degree less rigorous than in their native country. Be that as it may, the result is consolatory, and a satisfactory proof of what may be done by industry and perseverance. The surface of the ground has been cleared of granite blocks, and made to produce plentiful crops of grain; a safe and commodious harbour has been constructed in the face of a stormy sea; thriving manufactures have been established; even the granite itself has become a valuable article of export, and a community of 50,000 industrious inhabitants exist in full activity, and in the enjoyment of abundance.

DUNDEE HARBOUR.

[*See* Plates 38, 39.]

The town of Dundee is situated on the east coast of Scotland, in 56° 27′ north latitude, and 3° west longitude, and on the north side of the Tay estuary, which is there nearly two miles wide. About three miles below the town the estuary is contracted to half that breadth, and thence widens, until, at seven miles distance from this narrowed gorge, it is terminated, at the northern extremity of the Bay of St. Andrew's, by a bar, upon which there is from two to four, five, and six fathoms at low water of an ordinary spring-tide. All above Broughty Castle is a well-protected roadstead, with three to ten fathoms water. The expanse opposite the town of Dundee, and consequent retardation of current, has permitted the formation of a sand-bank; but as this does not occupy one-third of the waterway, and is in a longitudinal direction, plenty of space remains for navigation on each side of it.

Until the beginning of the present century, in consequence of the excellence of the roadstead, business was transacted with the aid of very imperfect wharfage on the shore. The hemp and linen manufacture has long been the staple of Dundee; and during the long-continued wars, from 1793 to 1815, canvas and coarse bagging were made in large quantities, by which, and engaging largely in the transport service, the industrious inhabitants increased their activity and wealth; and this being also the principal town and port of the Carse of Gowry,* with the extensive and thriving Strathmore * behind it, (the richest agricultural district of Scotland,) accumulated capital centered in the Dundee banks.

* *Carse,* alluvial soil; * *Strath,* a wide valley,—*more,* great,—*Strathmore,* The great wide valley.

On the termination of the war, employment of transports also ceased, and the intelligent merchants and manufacturers perceived that they must employ larger vessels for longer voyages, and seek more distant connexions; and that, with this view, accommodation for suitable shipping must be provided, in the same manner as had already been done in other places of much less promise and importance.

In fact, the growing prosperity of Dundee fully justified considerable efforts. The harbour-dues, in 1765, only produced a gross sum of £.126; in 1800 they amounted to £.1,300, and in 1814 to £.1,701. Until this time the harbour-dues were entirely in the hands of the corporation, collected and applied promiscuously with the town revenue; and in the ten years previous to 1815, although £.13,817 had been collected, no more than £.1,193 had been expended upon the harbour and wharfs. But it was now discovered that the prosperity of the port was connected with that of the district at large, so that not only the resident merchants and manufacturers, but the land-owners and agricultural capitalists, were zealous for harbour improvement. From the past conduct of the corporation, and their confined views, no prospect existed of obtaining suitable accommodation under their management, as indeed was fully evidenced by their instructions to me, which went only to forming wharfs and quays for a tide-harbour, and it was to this only my plan of 1814 extended; but I at the same time pointed out in what manner a floating-dock might be obtained.

A number of public-spirited individuals having interposed, overpowered the corporation, and the exclusive management of the harbour was put into the hands of public commissioners. From this date, enlarged views were developed, and a plan for an extensive floating-dock was formed, also for a graving-dock for large vessels, and for entrance-piers pro-

tecting the inner or western tide-harbour, which was to be greatly enlarged and deepened. An Act to this effect having been obtained in 1815, the works were prosecuted with successful energy, and the floating-dock was opened on the 23d November 1825, to the entire satisfaction of all parties. The trade has ever since enjoyed the desired accommodation, and instead of too much having been done, as foretold by the corporation, the dock has been found insufficient in extent; and in 1830, powers were obtained to construct additional new docks to the eastward.

The conduct of the Dundee corporation forms a striking contrast with that of Aberdeen. The management of the port was taken out of the hands of the former, because their views did not keep pace with the growing demands of commerce; whereas the latter have been exposed to obloquy and Parliamentary persecution for proceeding on too extensive a scale of improvement.

The Dundee floating-dock already completed is 750 feet in length, and 450 feet in breadth; its entrance-lock is 170 feet long and 40 feet wide. The floor of the graving-dock is 265 feet long, 40 feet wide at bottom, and 68 at top. There is 16 feet of water on the sill of the entrance-lock at high-water of an ordinary spring-tide.

The harbour-works were placed under the superintendence of Mr. David Logan, but he preferred employment at Donaghadee Harbour, when the Dundee improvements were about half completed, and was succeeded by his cousin Peter Logan, both of them active young men, who conducted the works to my entire satisfaction. The intelligent secretary of the trustees, James Saunders, has by his perseverance and enlightened conduct greatly contributed to the growing prosperity of

the port. I here annex information furnished by him in the year 1830.

The following are the average of tonnage, taken every three years:

		Tons.	
1799 to 1803, inclusive	- - -	63,519	annually.
1804 „ 1808 „	- - - - -	63,519	„
1809 „ 1813 „	- - - - -	69,293	„
1816 „ 1820 „	- - - - -	92,390	„
1821 „ 1825 „	- - - - -	123,186	„
1826 „ 1830 „	- - - - -	150,915	„

Or comparing two single years:

From May 1829 to May 1830	- - -	182,512
„ 1826 „ 1827	- - -	128,811
Increased Tonnage	- -	53,701

The expense of the works above described was £. 119,855.

From May 1816 to May 1817 - £. 5,900 harbour-revenue was collected by the Trustees;
and in 1829 „ 1830 - 11,645 - - - „ *

Previous to 1815, when the improvements were commenced, the greatest import of flax and hemp in one year was 3,000 tons; in the

* The unavoidable delay in publishing Mr. Telford's posthumous work has rendered necessary a request to Mr. Saunders for continuation of the above statement to the present time, and he has furnished it with the greatest readiness, as also a description of the progress and mode of the enlargement of harbour accommodation under the Act of 1830. The additional statement and description by Mr. Saunders is as follows:—

STATEMENT of INCREASE of TRADE.

The staple trade of Dundee being linen, nothing will better exhibit its gradual increase than the gross tonnage of raw material imported:—In one year ending May 1830, tons 18,557 were imported; in 1831, tons 22,259; in 1832, tons 18,092; in 1833, tons 22,157; in 1834, tons 26,165; in 1835, tons 25,159; in 1836, tons 29,565; in 1837, tons 34,149. Up to this last date there has been a gradual increase, and by no means to such an extent as to exhibit any thing like the prime cause of the numerous bankruptcies which took place.

But perhaps a more certain index of the gradual increase of the general trade of the town is to be found in the quantity of coals annually imported, not only because it is an article of general private consumpt in every family, as well as an article greatly used in

year ending in May 1830, it became 18,557 tons; in the year ending in May 1831, there was shipped 356,817 pieces, measuring 50 millions

carrying on our manufactures and shipping trade, but because it is an article so near at hand that the importation can be nicely regulated by the demand. Speculation, indeed, produces no over-importation of this article. The gross weight of Scots and English coals for the seven last years is as follows:—

May 1831	- - - - - - -	275,431 Bolls.
„ 1832	- - - - - - -	299,636 „
„ 1833	- - - - - - -	328,724 „
„ 1834	- - - - - - -	339,635 „
„ 1835	- - - - - - -	404,017 „
„ 1836	- - - - - - -	454,290 „
„ 1837	- - - - - - -	529,061 „

Thus, within the last seven years, the importation of coals for the wants of the population and surrounding country has nearly doubled. But the increase is chiefly on the town's consumption, because a very few more tons of coals annually are now required for the country than has been required for the past thirty years. It may be instructive, too, to notice, that, in the year 1825, when King William's Dock was first opened, the importation of coals was 183,867 bolls, or nearly one-third only of the importation of 1837; so that this mercury has been gradually rising as the population increased, from the commencement of the harbour improvement down to the 31st of May 1837.

Another index of the gradual increase of the trade is the tonnage of shipping which has annually entered the harbour for the last seven years.

May 1831	- - - - - - - -	189,326
„ 1832	- - - - - - - -	191,486
„ 1833	- - - - - - - -	212,025
„ 1834	- - - - - - - -	220,768
„ 1835	- - - - - - - -	259,736
„ 1836	- - - - - - - -	293,119
„ 1837	- - - - - - - -	286,662

DESCRIPTION OF HARBOUR IMPROVEMENT.

In 1831, Mr. Telford was consulted as to the best manner of converting the then western tide-harbour into a wet-dock, and he employed Mr. Gibb, of Aberdeen, to prepare a plan and specifications, which were examined and revised by Mr. Telford, and the dock was commenced in the same year. The harbour trustees, in the year 1832, appointed, as superintending engineer, Mr. James Leslie, who had been instructed in mathematics by his late uncle, Professor Leslie, and afterwards, for education in his profession, was placed under Sir John Rennie. Mr. Telford's plan was executed by Mr. Leslie nearly according to the original design; but, owing to the large dimensions of the splendid steam-packets intended for the London trade, in the same year, 1832, it was deemed expedient to increase the width of the lock from 45 to 55 feet, and the length between the gates to 210 feet. The depth of the lock was also increased one foot, so as to make the depth on the sill at high water of spring-tides, 19 feet, and 14 in ordinary neap-tides.

of yards; also sail-cloth, 85,522 pieces, measuring 3½ millions of yards; and bagging, 62,199 pieces, measuring 4 millions of yards; total, 57½ millions of yards. The value of hemp and flax imported, £.700,000; of goods shipped, £.1,500,000.

Since the harbour has been completed, a considerable number of large vessels are employed in trading with the American United States, British America, South America, and the West Indies; and hemp, flax and tallow, are imported from Archangel in the North Sea, from Petersburgh, Riga, and other ports in the Baltic.

In the enumeration of 1801, the town appears to contain 26,804 inhabitants; in 1831, the number was 45,355.*

As the trustees were not aware of any instance of cast-iron gates being exposed to the action of the sea, they had some misgivings as to the propriety of making such large gates of cast-iron, in a situation which is much exposed to the action of the waves, while, on the other hand, the difficulty and expense of procuring timber of sufficient scantling for the bars would be very great; the timber being also liable to be destroyed by the *limnovia*, commonly called the sea-worm, which was afterwards found to have completely destroyed the lower bars of the wooden gates of King William's Dock, erected in 1825.

The plan and specification of the intended iron gates, as prepared by Mr. Leslie, were sent to Mr. Telford for his opinion, which was favourable, and he returned them with some small modifications. The dock-gates have been executed accordingly, and are found to be very tight, and to answer every purpose; they are planked on both sides so as to give them buoyancy, and to prevent the waves from striking under the cross-bars, and lifting or shaking the gates.

This dock (which was named Earl Grey's Dock) was completed and opened in November 1834. The expense of the masonry work of the lock was about £.9,000 and the two pair of iron gates about £.3,000.

The extensive works to the eastward of King William's Dock were commenced in May 1833. From low-water to very high water of spring-tides, the rise of tide is 19 feet at Dundee.

* According to an Estimate by Mr. Saunders (1837)—" The population now exceeds " 60,000, or three times the number at which it was estimated when the harbour improve- " ments commenced."

TAY FERRIES AT DUNDEE.

[*See* Plate 38.]

In the intercourse between Edinburgh and the towns on the east coast, it has always been desirable to traverse in a direct line the county of Fife to Dundee, instead of the circuit by way of the Queensferry and Perth, thereby to effect a saving of 25 miles; but in the direct line two ferries intervene, the one of seven miles, the other nearly two miles across, and the passage of these by sailing-boats was tedious, and not unfrequently dangerous; but since steam-boats have been in use, and suitable landing-piers constructed, the chief obstacles have disappeared.

Dundee being the principal market for agricultural produce, and also the residence of many of the flax-spinners who have occasion for daily intercourse across the ferry, the counties of Fife and Forfar agreed to improve the passage, Fifeshire promising £.4,750, Forfarshire £.16,250 for this purpose, and in the year 1819, they obtained an Act accordingly; but in the course of two years, the plan they had procured was judged to be unsuitable, wherefore in the year 1822 they obtained an amended Act for Ferry-piers, according to plans furnished by me, which were carried into effect, one on each side of the river; whereupon steam-boats were established, and passages are now made regularly every half hour. Messrs. Carmichael, of Dundee, constructed twin boats, with a paddle-wheel in the middle; each boat has its engine of thirty-horse power, is 92 feet in length, and 34 in breadth, affording ample space for passengers, carriages and cattle, which enter and depart with ease and safety, from masonry slips properly sloped for accommodation at all times of the tide. The landing-place on the north is nearly 150 yards in length, and, besides a protecting

parapet and raised footpath, has a paved slip for carriages and cattle, 30 feet wide, and it is furnished with arched passages near its foot for the flux and reflux of the tide, so as effectually to scour the back of the protecting pier of the western harbour. On the south side are two connected slips, with a protecting wall between them, thus sheltering the boats and the embarkation in all winds, and in every state of the tide. These piers, with their slopes or slips, were built under the superintendence of Mr. Peter Logan, whose conduct continued to merit my approbation. The expense of constructing the piers and approaches was £.24,600.

At this ferry station are three steam-boats, one of them starting from Dundee every hour. The passage is effected in from 18 to 25 minutes, according to the state of the weather. An account of the passages in the year 1830 is subjoined.

Passengers - - - - - -	92,658
Horses - - - - - - -	4,320
Neat Cattle - - - - - -	4,098
Sheep - - - - - - -	10,840
Four-wheeled Carriages - - - -	273
Gigs - - - - - - -	594

Before the improvement of the ferry, that is, in the year 1820, the fares amounted to £.2,747; in the year 1830, to £.4,936.

ST. KATHARINE DOCKS.

[*See* Plate 40.]

The formation of the St. Katharine Docks, adjacent to the Tower of London, is so much connected with the history of docks previously made on the banks of the river Thames, that introductory matter to some extent is indispensable for the information of the reader.

The facility of transit afforded by regular tides, in an embanked river or estuary, such as the Thames, which in ordinary spring-tides rises 18 feet perpendicular in the middle of the City, enables commerce to be carried to an unprecedented extent, and the other advantages enjoyed by London have created capital, habits and connexions commensurate with that commerce, which, by its vast increase, reacts upon and augments the prosperity of this great city, now become a commanding *entrepôt*, or mart, affording such opportunity of assortment, that every ship arriving with a mixed cargo, or seeking a mixture of merchandize for her outward voyage, cannot fail to prefer the Port of London to any other, if accessible at a moderate expense of time and outlay.

Being also the capital of an empire, which extends into every quarter of the globe, and combining legislation, commerce and manufactures with a well-regulated police, and a mild and just administration of government, industry finds scope for her utmost powers, and so much ingenuity and perseverance is thus created as to overcome every obstacle, and deservedly to entitle the British Metropolis to the admiration of the best-informed and most civilized nations of the earth.

The commercial prosperity of England, which originated and still centres chiefly in London, extended itself to the outports, which, not enjoying the same local advantages, have had recourse to artificial means of acquiring accommodation; for instance, the Port of Liverpool, above a century ago (A. D. 1702), converted a small pool (from which it takes its name) into a wet-dock, which preserved vessels afloat, and gave facility to mercantile operations; and as commerce increased, other docks were added, and connected with canals subsidiary to the manufactures of the adjacent territory. Other outports, moved by a

spirit of emulation, had recourse to similar accommodation, and the improvement of these outports added to the crowded state of the river Thames, and the increasing tonnage of ships employed in distant voyages, rendered it imperative on the Metropolis to relieve the merchant shipping from the necessity of discharging their cargoes in the tideway, subject to inconveniences of all kinds, depredation not excepted.

Thus urged into action, capital and intelligence displayed unprecedented activity, wharfs and magnificent warehouses were created along the river bank, to an extent which can only be appreciated by personal inspection, and floating-docks, containing upwards of 120 acres, have been constructed, leaving the entire river and the ancient wharfs to be occupied by the shipping employed in the coasting and local trade. These grand improvements commenced with the present century, at the end of the year 1799, when a company, whose views were chiefly directed to the West India trade, was incorporated by Act of Parliament. For the site of their operations, they selected the neck of a river peninsula, opposite to the town of Greenwich, where the surface of the alluvial ground is so much below high-water as to have required all the excavated earth from the dock to form the surrounding wharfs. The shape of the peninsula also admits of the docks having one entrance at Blackwall from the eastward, and another at Limehouse, for the western connexion with the river; the intermediate space is laid out in two parallel docks; the north dock, appropriated to the inward trade, extends over 27 acres; the south dock, of 24 acres, is for the outward-bound trade; to the north are ten large stacks of warehouses, each capable of containing 8,000 hogsheads of sugar. The south side is chiefly appropriated to rum. The entrance basins are eight acres each, including which, the docks are capable of containing, at one

time, 600 vessels, employed in the West India trade. The capital stock of the Company was at first £.500,000, afterwards augmented to £.1,200,000, and their exclusive privileges, as to the reception of West India commerce, expired in 1823. These docks were judiciously planned by that able engineer, Mr. W. Jessop, and the warehouses by Mr. Gwilt; every thing was favourable, except the distance from London, these docks being four miles from the Royal Exchange.

No sooner were the West India Docks in progress than another Company was formed, for the accomplishment of a still more expensive project; but they persuaded themselves that this great expense would be more than compensated by the site being nearer to the City, and they assumed the title of the London Docks, the Company for making which was incorporated by Act of Parliament in 1800. They fixed upon the lower part of Wapping, which was covered with houses of a very inferior description, and very many of them had been recently consumed by a destructive fire, more extensive than any other since the tremendous conflagration of 1666; but little noticed at that time, and scarcely now remembered, from the comparative obscurity of the situation, in which were no public buildings whatever.

The plan of the London Docks was formed by the late Mr. Rennie; but the Company, having an exclusive privilege for the wine trade, and some other branches of commerce, sought their own profit in the usual short-sighted spirit of monopoly, and completed but one dock, which, with an entrance basin, occupies a space of 23 acres, calculated to contain 230 ships at one time, with warehouses, planned by Mr. Alexander, for 25,000 hogsheads of wine, and as many pipes in the vaults. These docks were opened in January 1806. The original capital stock was £.1,200,000; by several successive Acts, since raised to £.3,200,000.

The exclusive privileges of this company ceased in 1826, not without furnishing a memorable instance of the baneful nature of monopoly; for although they had forborne to spend any part of their profits in making a second dock, as at first promised, and had created grievous loss in demurrage, by inadequate accommodation, yet when another Company undertook to make the St. Katharine Docks, the London Dock Company found it their interest to fulfil their original intention, although powerful rivals were now to share the business and the profit.

To the West India Docks and the London Docks was added a third, at a little distance below the West India Docks, at Blackwall, under the title of the East India Docks, consisting of an homeward-bound dock of eighteen acres, an outward-bound dock of nine acres, and an entrance basin of nearly three acres. The capital, at first, was £.200,000, afterwards augmented to £.600,000. These docks were planned by Mr. Ralph Walker, and their exclusive privileges ceased in 1827; they are situated full four miles from the Royal Exchange, but not quite so far from the East India House, with which they were soon more immediately connected by means of the *Commercial Road.*

Notwithstanding the before-mentioned enlargements of space, so great was the commerce of the Port of London, and so high the charges of the London Dock Company, that a number of principal merchants, in 1824, formed a scheme for constructing new docks, still nearer the heart of the City than even the London Docks, their *Prospectus* promising the public more moderate charges, with more convenient arrangements [*see* Appendix (I.)]; and the Committee of Management, having selected the space between the Tower and the London Docks, which included the site occupied by St. Katharine's Hospital (a royal foundation of ancient date), that title was assumed by the St. Katharine Dock

Company. The Committee then placed a map of the premises in my hands, explaining what accommodation they required, and requested me to form a plan accordingly. The whole extent is no more than twenty-seven acres of a very irregular figure, so that, when the space necessary for warehouses and entrances was subtracted, ten acres only remained for the actual docks, which therefore required an unusual arrangement so as to provide wharfage and quays for the various branches of trade expected to frequent them. It being obvious that the accommodation required could not be obtained by the simple forms of squares and parallelograms, I was, from necessity, led to adapt the shape of the docks to that of the ground; and this was so managed, after attentive consideration, as to become really advantageous, as affording an increased extent of wharfage, and two docks instead of one, by which distribution the trade was likely to be better arranged; with a further advantage, that in case it should at any time be found necessary to empty one dock, the water may be retained at full height in the other.

These docks communicate with the river by means of an entrance tide-lock, 180 feet in length and 45 feet in width, with three pair of gates, admitting either one very large or two smaller vessels at a time. The lock-entrance and the sills under the two middle lock-gates are fixed at the depth of ten feet under the level of low-water mark of an ordinary spring-tide. The vessels pass from this lock into an entrance basin of about two acres, and thence in one direction, by a single pair of gates of 45 feet in width, into the eastern dock of about four acres, and by similar means into the western dock, of equal area. The bottom of the docks and basin is four feet above the outer and middle lock sills, and the height of the quays is eight feet above the water in the docks; this water, as well as that in the basin, being preserved always at the same level by means of the tide, aided by two of Mr. Watt's steam-engines,

of 80 horse power each; and as these engines can fill the lock in seven minutes, the process of lockage may (without affecting the basin) be continued as long as there is sufficient depth of water outside the lock-gate sill for the vessels which have occasion to be passed. On the 21st of September 1829, within twenty-four hours, fourteen vessels passed inwards and three outwards, some of them 400 tons burthen; and 92 vessels have been in the docks at one time, some of them not less than 800 tons burthen.

The small area of the docks, with only one entrance, led to employing steam-engine pumps for accelerating the lockage, and to laying the lock-sill so much under the level of low-water on the shore, whereby the length of time for the admission at every high-water is greatly increased. These resources, in similar difficulties, are not undeserving the attention of future engineers. [*See* Plate 42, and Appendix (I.)]

The St. Katharine Dock Company had to encounter much opposition from the previously established docks, yet the Act was obtained in June 1825. The houses and ground were forthwith purchased and cleared away; detailed working plans prepared, the excavation commenced, and the foundations of the masonry laid on the 3d of May 1826, before the expiration of a twelvemonth; and such was the energy with which every operation was conducted, that the entrance-lock, basin and western dock, with their surrounding piles of warehouses, were completed and opened for business on the 25th of October 1828; and on the 25th of October 1829, vessels were also admitted into the eastern dock.

Seldom, never indeed within my knowledge, has existed any instance of an undertaking of this magnitude, in a very confined

situation, having been perfected in so short a time; nor could it have been accomplished in any other place than London, where materials and labour to any extent are always to be procured, as likewise the command of capital in the power of intelligent directors, accustomed to transactions on a large scale. The extreme rapidity with which every operation was forced on was doubtless defensible, as useful and desirable in a mercantile speculation, with the view of having a speedy return for the advance of large sums, and for encouraging future advances, also for meeting the urgent demands of increasing commerce; but as a practical engineer, responsible for the success of difficult operations, I must be allowed to protest against such haste, pregnant as it was, and ever will be, with risks, which, in more instances than one, severely tasked all my experience and skill, involving dangerously the reputation of the directors and their engineer.

Having given detailed drawings, and in the Appendix inserted a copy of the general specification, I shall only further notice, that the busy intercourse between the numerous wharfs and warehouses along the Wapping shore of the Thames rendered it necessary to provide, as far as practicable, against stoppages and interruption; the street was therefore widened, and the wharfingers contended for two bridges across the entrance-lock; but this I opposed, as equally inconvenient to the shipping and the land-carriage, and a bridge of cast-iron, 24 feet in breadth (a turn-bridge, moving horizontally), was so accurately constructed, that by two persons, stationed one at each end, the bridge is worked with ease. [*See* Plate 41.] The entrance-lock is built chiefly of grey stock-bricks, laid in mortar made with lias-lime; the platforms, hollow quoins,* bond-stones and copings of the lock-walls, are of the

* The hollow quoin-stones form a half tube of masonry, in which the heel-post of the lock-gate is placed, and turns with the utmost accuracy, incurring small loss of water.

best Yorkshire Bramley-Fell stone, and the whole is now cemented into a solid mass. Three pair of gates of suitable dimensions, accurately formed, and fitted so as to be perfectly water-tight, complete the apparatus, and render the whole worthy of its important purpose. On the eastern side of the lock, as has been already mentioned, a substantial engine-house contains two of Mr. Watt's 80 horse power engines, furnished with three boilers (for sure resource in case of accident or renewal), and these engines may be brought into operation at once or separately. They draw water at the lowest ebbs from the river, through a conduit or culvert 170 feet in length, very difficult and expensive in construction, and this water flows at pleasure either into the lock (filling sixteen feet of its depth in seven minutes), or into the inner basin, for occasional supply from the bottom of the lock-chamber, from which cast-iron pipes also communicate with the engine, whereby, and by shutting the lock-gates, the ten feet depth of water under the level of low-water on the shore may be pumped out when any temporary repair of the lock-chamber is required; and besides performing these varied operations, the engine fills a cistern always ready for use in case of fire. Upon the whole, when it is considered that my friend, Mr. James Watt, and his able and ingenious assistant, Mr. Murdoch, with their best workmen, spared no pains in the construction of this important machine, I am justified in assuming it to be most excellent, and such as may be described and exhibited as a masterly specimen of British mechanism. [*See* Appendix (I.)]

A considerable part of the space occupied by the docks and quay-walls is a stratum of gravel; and here it was not only necessary to line the bottom of the docks, and puddle the back of the walls, but also to place the walls and Counterforts upon a foundation impervious to water. This I originally proposed to prepare from earth excavated from the upper parts of the docks; but upon trial, this was found to be quite

unfit, as it softened in water, and was squeezed outward, by any weight placed upon it. I was therefore under the necessity of substituting an artificial concrete, composed of one part of blue lias-lime, mixed with eight parts of coarse sand, and kneaded into thick mortar, a bed of which, about twelve inches in thickness, was spread largely enough to contain on it the breadth of the base of the wall, Counterforts* and puddle; moreover a wooden sill was laid under the front edge of the wall, and a row of Sheeting-piles,* fourteen feet in length and nine inches in thickness, were driven along the side of it, their joints, for three feet downwards, being closely caulked. The facing-wall of all the quay, to fourteen inches within its surface, was laid in blue lias-lime mortar; the remaining thickness was worked with Dorking lime mortar. The bricks were flushed,* and every four courses varied in their diagonal direction. I had previously, by experiments, proved the qualities of the different limes when made into mortar, and found that the blue lias, when immediately exposed to water, indurated quickly and perfectly. Dorking lime, when suffered to dry slowly, is sufficiently good. By constructing walls in the manner thus described, although the floors of the vaults are four feet under the constant level of water in the docks, no percolation can any where be perceived, which I attribute chiefly to the lias-lime mortar; as I am informed that, in some other docks, much expense has been incurred after the walls were built. This I mention to show what precaution is necessary in building dock-walls. The form of the mooring-rings attached to the quay-walls is, I think, new, and also deserving of attention.

* Civil Engineers must sometimes excuse explanations superfluous to themselves. A *Counterfort* is an internal unseen buttress, whereby a wall is secured immoveably in its intended position.—A *Sheeting-pile* has more breadth than thickness, and is much used in constructing Coffer-dams.—The internal brick-work, or core of a brick-wall is said to be *flushed*, by pouring into it liquid mortar, in the manner of *grouted* masonry in stone-work.

By adopting every improvement which could be suggested, new facilities were afforded to the trader; for instance: the warehouses, by standing on the front edge of the wharf-walls, admit vessels to lie alongside, and the goods to be discharged at once into the different lofts or stories, without the trouble and expense of landing-sheds and railroads. But, in the first place, it is to the intelligence and activity and perseverance of the secretary, Sir John Hall, in carrying the Bill through Parliament, to his exertions during the progress of the works, and the sagacious manner in which the several arrangements were adapted to the trade of the port, that the complete success of the establishment is chiefly attributable, especially as all this was accomplished notwithstanding the jealousy and watchful opposition of the existing Dock Companies. In the year 1830, being the second after the St. Katharine Docks were opened,

500 loaded Ships entered inwards with -	98,013	Tons.
393 loaded Ships departed outwards with -	43,738	„
Making 893 Ships with - - - - -	141,751	Tons.

In fact 105,398 tons of goods were landed, and 83,780 delivered: the increasing stock of goods in the warehouses, on the 31st of December 1830, being 50,773 tons.

The Total Receipts and Rents in 1830 was - - -	£. 107,787
„ Expenses and Charges „ - - - - -	57,436
Net Revenue of the Dock-Company - -	£. 50,351

With regard to the rapidity with which the works were performed, and the risk and difficulty of laying foundations so much under the level of low-water, the chief merit is due to Mr. Thomas Rhodes, who had been, during many years, employed by me as a complete master in carpentry, and who on my recommendation acted at first as foreman, and afterwards as resident engineer in the entire formation of

the St. Katharine Docks, where his dexterity as a mechanic, and fertility of resource, overcame every obstacle in constructing cofferdams under a lateral pressure of 40 feet of water; and the water-tight security of the wharf-wall foundations, as well as the perfect accuracy of the locks, their sills, gates and bridges, afford especial evidence of his superior skill and unremitting attention.

THE GOTHA CANAL, IN SWEDEN.

[*See* Plate 43.]

From information furnished by my late friend, Count Platen (by whose death, while Viceroy of Norway, the kingdom of Sweden has sustained a serious loss), I was enabled to give to the Edinburgh Encyclopædia an historical account of the inland navigation of Sweden. To this I must now refer [*see* Appendix (K.)] for a complete and satisfactory view of the subject, and also of inland navigation in general, as I here intend to confine myself chiefly to that particular canal which was planned, and afterwards completed, under my direction; and for this purpose it is necessary, first, to give a short statement respecting the Trollhatta Canal and the river Gotha. From Wenernsborg (where the river leaves the great lake Wenern) to Gottenburgh, the distance is 50 miles, and the fall is 144 feet. Near Wenernsborg, two connected locks have long existed, each 182 feet in length and 34 feet wide; they were constructed about the year 1600, in the reign of Charles IX. by Dutch engineers, probably under the direction of John of Ostrogotha, who had travelled much, and seen such inventions; he died in 1618. In 1793, a plan for passing the Trollhatta Falls was laid before the then King, by a company of subscribers; this consisted of a cut from a small bay, immediately above the falls, along a rocky bank, to a small lake, and it thence descended by eight locks (making 112 feet) into the river,

at a considerable distance below the falls, where the current is placid. To encourage the projectors, the lock at Edit, built on the river Gotha in 1640, and that at Akerstrom, built in 1774, were granted to the company, on condition that the Trollhatta Canal should be made twenty-two feet wide, with not less than six-and-a-half feet of water. M. Nordwall was appointed chief engineer, and the canal and locks were completed in 1800. The navigation of this canal produces nine per cent. upon the capital invested.

The Count Platen, having retired from the sea-service, and purchased an estate in the neighbourhood of Trollhatta, was elected a director of that navigation, and very soon perceived the advantages that would be derived by continuing a similar communication between the Wenern and the Baltic, by which, in case of war with Denmark, the navigation of the *Sound* might be avoided, while, by uniting the great lakes, an opening would be afforded for exporting their produce of timber and iron, also for conveying the limestone (which is chiefly found on the shores of the lakes) to the interior of the country, for agricultural purposes; and Count Platen, having determined to devote himself to this object, had sundry conferences with the King, who, being convinced of the value of the project, authorized him to procure an accurate survey, made by an experienced British engineer; and thus authorized, he made inquiry for a person engaged in similar undertakings. Being at that time employed on the Caledonian Canal, which consists in connecting lakes with each other, and with the tideway, on a larger scale than that proposed in Sweden,—the Count (in 1808) therefore applied to me; and having acceded to his proposal, I, with two assistants, went over to Sweden, and commenced operations early in August, and by the aid and judicious arrangements of Count Platen, I executed a regular survey, and laid down correct plans and sections of the

country between Lake Wenern and the shore of the Baltic, near Soderkoping, and made a detailed Report on the subject [*see* Appendix (K.)]; and having completed this arduous service, I embarked at Gottenburgh for England early in October.

The length of this navigation, from the Wenern to the Baltic, is about 120 English miles, 55 of which is artificial canal; the rise from the Wenern to the summit is 162 feet; the fall to the Baltic is 307 feet; the number of locks is 56; the width of the canal at bottom is 42 feet; depth of water, 10 feet; length of locks, 120 feet, and their breadth, 24 feet. In Plate 44 is shown a double lock of these dimensions; and in Plate 45, a double stop-gate and a timber drawbridge.

The subscription was opened in May 1810, and at the first meeting Count Platen was appointed chairman and manager-in-chief; and this appointment was confirmed by the King.

In 1810, the number of Workmen was - - -	1,000
1811 - - - - - - - -	5,000
1812 - - - - - - - -	6,300
1813 - - - - - - - -	7,000

But this year, on account of the demands of the war for soldiery, they were reduced to 3,000.

In August 1813 I again visited Sweden, and inspected all the works then commenced, which consisted chiefly of excavations. On this occasion the sites of the locks were precisely determined, and drawings made for them and the bridges. With the sanction of the British Government, I had previously furnished patterns of canal tools and utensils, and I now carried with me experienced lock-builders and earth-workers, to instruct the natives.

The Count afterwards made a voyage to England, and accompanied me in my inspections of our canal works; and on his return to Sweden,

he carried with him an experienced mechanic, to take charge of an iron foundry which was to be established on the line of the canal at Motala. From this time, indeed from 1813 to 1829, the Count sent me at least once every year a detailed statement of the canal operations; and he uniformly behaved with attention and kindness to the British workmen whom I sent over from time to time, as required.

When the canal was completed, and opened for public use, large gold medals were struck on the occasion, when one of each was presented to me;* and as a further mark of the King's approbation, I received a Swedish order of knighthood, and a portrait of his Majesty set in valuable diamonds.

HIGHLAND ROADS AND BRIDGES.

[*See* Plate 58.]

Having already, when treating of the Caledonian Canal, stated, that in my Report to the Lords of the Treasury was included the improvement of the Northern Highlands of Scotland by roads and bridges, and the formation of harbours and landing-piers on different parts of the coast, and as my advice was followed in all things connected with engineering, it becomes a duty incumbent on me to give a general view of what has been performed since 1803.

A minute detail of the transactions of twenty-eight years, in which the complicated interests of a great portion of Scotland were involved, occupies many Reports to Parliament, and is not requisite for what I have in view; that is, a short explanation of the practical progress

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* These medals are deposited at the Institution of Civil Engineers, and accurate engravings of them are here inserted.


CARL XIII SVERIGES GOTHES OCH WENDES KONUNG


CARL XIV JOHAN SVERIGES NORRIGES GOTHES WENDES KONUNG

and beneficial results of the numerous works performed under the sanction of the Parliamentary Commissioners; and this will, I conceive, be best accomplished in a summary manner under proper heads.

In my Report to the Lords of the Treasury, made in the autumn of 1802, I stated, that previous to 1732 the roads in the northern parts of Scotland were mere tracks; and although, between 1715 and 1745, a few military roads were formed, and afterwards many more, they were little adapted to civil purposes; that although bridges were then constructed over some of the smaller streams, yet the principal rivers could only be crossed by inconvenient and dangerous ferries; namely, the rivers Tay, Spey, Beauley, Conon, the inlets of the Meickle and Little Ferries (now superseded by Bonar Bridge and Flect-mound), and beyond them, the Helmsdale River, on the road to Wick and Thurso, all on the main line of road to the extremity of the Highlands. On the western side of the island, the military road, commencing near Dumbarton, passed through Inverary to the Black Mount,—down the narrow rocky pass of Glenco, to Fort William,—and along the Great Glen, with a branch to Bernera Barracks opposite the Isle of Skye,—in all which routes the roads were equally rugged, and almost impassable.

In order to procure correct information respecting the general intercourse, and other objects of inquiry, I submitted some queries to the Highland Society of Scotland, which, with their replies, I have inserted in the Appendix (L.)

The Committee of the House of Commons, to whom the consideration of my Report of 1802 was referred, after much investigation and the examination of many witnesses, made a favourable Report (June 1803), which will also be found in the Appendix.

In consequence of the recommendation contained in this decisive Report, a Board of Parliamentary Commissioners was appointed in 1803; and having, in the course of 18 years, accomplished most of the objects suggested in my Report, they, in 1821, in their Ninth Report to Parliament, gave a general statement of the various works which had been performed under their authority; and a copy of this Report (introduced in the Appendix) is the most satisfactory account which can be given, whether in regard to the number and extent of the undertakings, the expense incurred, or the manner in which this expense was defrayed.

By referring to the map of Scotland [*see* Plate 58], it will be seen that the Highlands have been completely opened by the new roads, and by repairing and improving the old military roads. Taking Carlisle as a link connecting the manufacturing districts in the north-west of England with those of the south-west of Scotland adjacent to Glasgow, and from thence, by lines passing through the counties of Perth, Aberdeen, Inverness, Ross, Sutherland and Caithness, in a northerly direction; and also through Argyle, and the Islands of Mull, Jura and Islay, to the north-west,—these roads, bridges and landing-piers, as enumerated and described in the Commissioners' Report, constitute an amount of improvement scarcely equalled in any other part of the world, within the same number of years.

To convey a distinct notion of the practical operations, it will be convenient to treat separately of Highland Roads and Bridges,—Lowland Roads,—and Landing Piers,—giving a short description and (in the Appendix) detailed specifications of the manner in which each of them has been constructed.

Highland Roads and Bridges.

As observed in my Reports to the Commissioners, the construction of a Highland road is very different from that of a Lowland road; the former, being chiefly for the accommodation of Highland cattle, requires to be freed from hard substances, which would injure their feet; and being generally formed along steep hill-sides, and encountering occasionally rocky precipices, such roads are made only of sufficient width to admit the meeting of two small carts.

The origin and progress of a new Highland road was thus arranged: An application, signed by one or more land-owners, was addressed to the Commissioners, stating that a road through a certain district would be of great public and private utility, and that the proprietors were willing to contribute one-half of the expense of making it. The Commissioners then directed me to examine the district in question, and produce a survey, report, and estimate. If the Commissioners approved of the proposed road, as reported by me, the memorialists were called upon to lodge one-half of the estimated expense in the Bank of Scotland. This performed, I was directed to prepare detailed working drawings and specifications, and especially to mark out the precise line upon the ground. Great attention was requisite in choosing the most commodious direction; and as the route was generally very rugged, in the early operations I attended to this personally, and afterwards appointed one of the superintendents, who had assisted in the survey, to show the line, also the plan and specifications, to those who sought to become contractors. If the whole extent of the road did not exceed ten miles, it was generally contracted for in one lot; but as many of the surveyed roads were from twenty to thirty, or even fifty miles in extent, these were divided into several lots, for which separate

proposals were required. All proposals were sent sealed to Mr. James Hope, the law-agent of the Commissioners at Edinburgh, who communicated them to the Board, through their Secretary, Mr. Rickman. For several years the lowest offer of contract, if accompanied by sufficient security, was accepted; but experience induced the Board to modify this practice, upon its being discovered that road-makers and others, previously entangled in difficulties, sometimes prevailed on persons to whom they were indebted to become their sureties, with the view of benefiting by the advance of one-eighth, made at the commencement of the work, to enable contractors of small capital to become competitors; such advance of one-eighth being gradually retained and absorbed, so that at the end of the work one-eighth remained due by the Commissioners; but some of the contractors and their sureties misapplied the first advance, and in a short time failed in their contract. This conduct, after much vexatious delay, led to strict inquiry into the sufficiency of those who offered to contract, thus far deviating from the general rule of preferring the lowest offer; an amendment which eventually was found to be satisfactory and really economical.

A contract having been entered into, in conformity to annexed plans, sections and specifications, the road-making proceeded under the management of a general superintendent and a special inspector, appointed by me. The last of these made a monthly statement and valuation of the work performed, which was transmitted through the law-agent to the Commissioners. By adhering to this mode, and persevering in the enforcement of strict attention to the specifications, the various works were performed, even in the most remote and rugged districts, with a remarkable degree of perfection; and for unquestionable evidence to this effect, the contributors of a moiety of the expense, and

the agents for the county in which the road was situated, were invited to attend the final inspection, and join in a certificate that the road was executed in the terms of the contract and specification, previously to the final payment of the retained one-eighth; and in this manner the whole of the roads enumerated and described in the Appendix were successfully completed, under 120 separate contracts, without once having recourse to a court of law.

From the slovenly and imperfect manner in which road-making had been previously conducted in the Highlands, and from the insufficient inspection exercised, the introduction of strict specifications, enforced to the letter, was at first unexpected by the contractors, who therefore suffered from their own inadequate estimates; but the uncompromising conduct of Mr. John Mitchell, whom I had recommended as general superintendent, convinced them that no relaxation from the specifications would be tolerated; and in the course of seven years, the mode I introduced was generally adopted in Scotland, and the contractors and their workmen became accustomed and conformable to it.

It must be considered that most of the new roads were, from the very nature of the intended improvement, to be carried through extensive districts, previously devoid even of a horse-track, or any accommodation for travellers; and that occasionally (as in the Sutherland or Tongue road) the lime for mortar was of necessity carried upwards of twenty miles in sacks on horses' backs, or (as in the Isle of Skye) that arch-stones were imported by sea, (for although the district through which a road is carried may consist of rocky mountains, yet for many miles no stratified bed of stone may be found, so that in some places it is scarcely possible to procure stones for covering two feet drains, or for breast-walls, retaining-walls or parapets), and that similar

difficulties, in many cases, imposed a necessity of employing inferior materials, until the new line of road was rendered passable for carts, to some spot where flat-bedded stones could be procured, and that the distance in some situations was such that the breast-walls and parapets were built with inferior stone, laid in lime-mortar; which, in truth, although more expensive in the first instance, is in the end most economical. Add to these difficulties, that in the case of the Highland roads, it was required to penetrate the greatest extent of country at the least possible expense, because all the land-owners were desirous of having their property opened, although to advance one moiety of the expense bore hard upon their resources; yet the opportunity of obtaining the other moiety from Government was not to be neglected, more especially as their estates were to be assessed generally in repayment for all the new roads within the respective counties.

Explanatory of Highland road and bridge making, I insert in the Appendix a copy of the description and detailed specification of the particulars required by the contracts, taking, as a fair specimen, the contract according to which was made the Spey-side road, which has been in use for fourteen years, exposed to a Highland climate.

In the above-mentioned road of 12¼ miles in length, there are 70 cross drains, equal to 2 feet square each; 9 arches of 3 feet span; 1 of 4 feet; 2 of 6 feet; 2 of 8 feet; 1 of 10 feet; 1 of 16 feet; 1 of 20 feet; 2 of 30 feet; 1 of 35 feet; in all, 20 in number, besides the repairs of still larger bridges over the Spey and Avon. The total expense was £.6,734. 10*s*., which is about £.530 per mile. As this road is 20 feet in breadth, and has its full proportion of masonry, and as most of the others are only 16 feet in breadth, the average expense was about £.450 per mile.

The material for the body of the road was in general found either on the line, or selected from adjacent pits or hillocks. The mode of preparing and using it is described in the specification of the Spey-side road.

It has already been mentioned that the whole of the 920 miles of new roads, and 1,117 bridges, were, in the course of 18 years, constructed under 120 distinct contracts. This is a proof of what may be effected by a well-regulated system of detailed specifications, working drawings, and unremitting inspection. That these numerous works, although widely scattered over a mountainous country, have been performed in a perfect manner, is now proved by many years' experience.

The contributors, although they had no right to interfere in practical operations, yet, by residing in the neighbourhood, had constant opportunities of seeing the manner in which the roads were executed; and by the Commissioners' Reports, which were widely circulated, they were invited to communicate their observations. Hence it is satisfactory to state, that in the course of 18 years no remonstrance has appeared.

NUMBER and DIMENSIONS of BRIDGES built under the HIGHLAND ROAD and BRIDGE ACT of 1803.

Bridges of One Arch:	Nº.	Water-way.	Bridges of Two Arches:	Nº.	Arches.	Water-way.
Four feet - - span -	386	1,544	From 10 to 50 ft. span - Number of such Bridges -	13	26	643
Six feet - - - ditto -	226	1,356	Bridges of Three Arches:			
Eight feet - - ditto -	124	992	From 8 to 40 ft. span - Number of such Bridges -	16	48	1,236
Ten feet - - ditto -	69	690				

Bridges of One Arch:	N°.	Water-way.
Twelve feet - - ditto -	76	912
Fourteen feet - ditto -	2	28
Fifteen feet - ditto -	35	525
Sixteen feet - ditto -	15	240
Eighteen feet - ditto -	27	486
Twenty feet - ditto -	27	540
Twenty-two feet ditto -	4	88
Twenty-four feet ditto -	22	528
Twenty-five feet ditto -	3	75
Twenty-six feet ditto -	3	78
Twenty-eight feet ditto -	3	84
Thirty feet - - ditto -	16	480
Thirty-two feet ditto -	3	96
Thirty-six feet - ditto -	7	252
Forty feet - - ditto -	15	600
Forty-four feet ditto -	1	44
Forty-five feet - ditto -	5	225
Fifty feet - - ditto -	3	150
Fifty-five feet - ditto -	1	55
Sixty-five feet - ditto -	2	130
	1,075	10,198

Bridges of Five Arches:	N°.	Arches.	Water-way.
From 10 to 40 ft. span - Number of such Bridges -	2	10	222
Besides Bridges built by distinct Contracts; viz.			
Fairness Bridge - - Arches 36 + 55 + 36 ft. span	1	3	127
Alford Bridge - - - - 40 + 40 + 40.	1	3	120
Helmsdale Bridge - - 70 + 70.	1	2	140
Wick Bridge - - - - 48 + 60 + 48.	1	3	156
Craigellachie Bridge (Pl. 47) 150 + 15 + 15 + 15.	1	4	195
Potarch Bridge - - 65 + 70 + 65.	1	3	200
Ballater Bridge - - 34 + 55 + 60 + 55 + 34.	1	5	238
Lovat Bridge - - - - 40 + 50 + 60 + 50 + 40.	1	5	240
Bonar Bridge - - - - 50 + 60 + 150.	1	3	260
Conan Bridge (Plate 49) - 45 + 55 + 65 + 55 + 45.	1	5	265
Dunkeld Bridge (Plate 46) 20 + 74 + 84 + 90 + 84 + 74 + 20.	1	7	446
	11	43	2,387

Recapitulation.

	Number.	Arches.	Waterway.
Bridges of One Arch - - - - -	1,075	1,075	10,198
Ditto - Two Arches - - - - -	13	26	643
Ditto - Three Arches - - -	16	48	1,236
Ditto - Five Arches - - - -	2	10	222
Built by distinct Contracts - - -	11	43	2,387
Total - - -	1,117	1,202	14,686

In Plates 47, 48, 49, 50, 51, I have given plans of the several sorts of bridges; and I have inserted a table of dimensions, applicable to the common bridges, generally built with rubble-stone; also a general specification. These were, of course, varied according to circumstances. The larger bridges were chiefly built of squared sandstone, or constructed with iron arches, under suitable specifications. Eleven of the largest bridges in the Highlands were built under separate contracts, and are not included in the above average. The expense of these bridges varied from £.2,000 to nearly £.14,000. The largest of them is worthy of particular description in this place.

Dunkeld Bridge.

[*See* Plate 46.]

In approaching the Central Highlands of Scotland, the river Tay may be deemed the southern boundary. The intercourse along the eastern coast has, ever since the year 1787, been sufficiently well accommodated by an excellent stone bridge, which was about that time built at the town of Perth, over the river Tay, from a design and under the direction of Mr. Smeaton. But the road which at Dunkeld passes into the Central Highlands, was interrupted at the river Tay by two ferries, which were always inconvenient, and not unfrequently dangerous to travellers.

It was fortunate that Dunkeld was the residence of the Duke of Atholl, a nobleman who delighted in useful improvements. He readily agreed to abolish the ferries, and transfer the tolls paid at them to a stone bridge, on condition of receiving the usual public aid; and pecuniary arrangements having been accordingly settled with the

Commissioners, I was directed to furnish the necessary plans and specifications.

The river being large, and subject to heavy floods, it was proper to provide a great extent of waterway; and this was the more requisite, as the bed or channel consisted of gravel. The design, therefore, exhibited five large arches, and two small land arches:—of these, the middle arch is 90 feet span; the two on each side of it are each 84 feet span; the two next the shore, each 74 feet span; the two small land arches, each 20 feet span; the breadth across the soffit (rather more than that of the roadway) is 27 feet 6 inches.

As in the Plate (No. 46) of this bridge, the outlines and also the particular parts are correctly delineated, I shall only add, that the foundations were difficult and expensive; but as good stone was found within four miles, and great pains bestowed upon the workmanship, a substantial edifice was completed in 1809, which remains in a perfect condition. The total cost was £. 13,361, of which one-half was defrayed by the public.

So far was the Duke from opposing obstacles to the general improvement, that at his own expense he made a new road from the western end of the bridge, through the middle of his highly ornamental grounds, and along the base of the bold and lofty Craig-y-Ban, from whence, to the eastward, is an extensive prospect of the Tay valley, comprehending the Birnam Wood of Shakspeare, and other romantic scenery; while to the westward, the strait or fissure of the rock adjacent to the King's Seat, forms an appropriate portal to the Braes of Atholl, the Pass of Killicrankie, the waterfalls of the Tummel, the wilds of Rannoch, and all the peculiar features of the Central Highlands.

Road Repair.

From many considerations it will be obvious, that the maintenance of Highland Roads and Bridges in a perfect state requires unremitting attention; for although the passage of cattle, horses and light carts makes but a slight impression, the winter frosts and heavy rains sometimes inflict injuries which endanger a total interruption of intercourse. This requires the unceasing watchfulness of six superintendents, each having about 200 miles under his charge; the general inspector, moreover, visiting the whole in turn; such of the military roads as are still in use being included with the new roads made under the Highland Road and Bridge Act.

These Military roads, some of which have been in use during an entire century, seem to require preliminary notice and description. They were constructed for military purposes in the Highlands between the years 1732 and 1750, and maintained at the public expense; at one time they amounted to 800 miles, including no less than 1,000 bridges. They were dependent on the War Office until 1770, the commander-in-chief for Scotland having control over them, and under him the reparation was entrusted to an officer called the Baggage-master. From 1770 to 1783, the sum distinctly granted for this service was £.7,000 annually; for the next 20 years, £.4,700; and for the next 10 years, £. 5,500. Of this sum, the establishment, inspection and incidents amounted to £. 2,000; and the mode of conducting practical operations was by means of a general inspector, a sub-inspector, 16 overseers and master masons, and 270 workmen, who laboured by the day, from 100 to 120 days, during the summer season.

In 1798, Sir Ralph Abercromby stated that these roads were no longer necessary for military purposes. In the low country they were

then abandoned, or became turnpike roads, so that in the year 1814 the number of miles was reduced to 530; and upon investigation by a Committee of the House of Commons, it was considered improper to maintain a costly establishment at £. 2,000 per annum for such limited operations, when a public board existed for similar purposes in the same country. From that date, such of the military roads as the heritors of the counties through which they passed deemed worth preserving, were repaired and improved, under the direction of the Commissioners for Highland Roads, and have thus been restrained to 280 miles in length, and the expense to the public reduced from £. 5,500 annually to £. 2,800. A subsequent statement will show in what districts these, as well as the new roads, are situated, and at what expense they are maintained.

While the last of the new roads which required my frequent personal attention were in progress, I had ample opportunities of observing the effects of wear and weather upon those which were first made; and feeling convinced that their speedy ruin would ensue, if left to no better care than that of the land-owners,* I explained to the Commissioners the necessity of establishing a system of repair, under their own officers; and having, with their approbation, arranged this scheme, determined the several districts, and appointed the inspectors, for several years I carefully noted and reported its effects. The management of practical operations was entrusted to John Mitchel, as general superintendent, who conducted them admirably well, and with such unremitting

* Mr. Telford has omitted to notice, that an experimental Act of Parliament was passed in the year 1810, at the suggestion of the Commissioners,—"for maintaining and keeping in repair Roads made and Bridges built" under their authority, whereby the heritors were enabled to repair the new roads at the county expense. But this not having been once put into operation, a more effectual Act in the year 1819 became indispensable for maintenance of the new roads, and under this last Act Mr. Telford made his arrangements.

zeal as destroyed his vigorous constitution, and in the prime of life he fell a sacrifice to over-exertion, having frequently travelled 10,000 miles in the course of the year. He died on the 20th of September 1824. In their Report of 1825, the Commissioners record his well-merited eulogium, and they authorized me to procure and place, in the church at Inverness, a marble tablet, on which his services are inscribed. He was succeeded by his son, Joseph Mitchel, who had been from his youth familiar with Highland road-making, and by my advice practically exercised in masonry. He was also for some years in my immediate employment, where he acquired a knowledge of road-surveying. He has ever since been continued general superintendent, and is active and intelligent.

The mode in which the road repairs are conducted is as follows:—the general superintendent, once in every year, carefully examines every road, taking notes of its state, and estimating any defects; he then prepares a detailed specification, defining distinctly what is necessary to be done. Upon this a contract is entered into, either by public competition, or with some experienced road-maker; and I shall insert (in the Appendix) four Agreements, each adapted to a particular case.

1. Copy of a short and general Agreement, applicable to the repair of Roads made under the authority of the Parliamentary Commissioners.
2. Copy of an Agreement for the repair of the Military Roads, which had been for some years under the Commissioners' establishment, but not yet made sufficiently perfect; for example, the *Badenoch Road.*
3. For the first improvements of an old Military Road, which had been very imperfectly made, in the Atholl district; viz. *Strathgray to Pitlochy.*

4. For the improvement of an old and very imperfect county road, but which was much travelled, as extending from Beauley to the boundary of Ross-shire.

These cases afford a distinct view of the nature of Highland Road and Bridge repairs. Much, however, depends upon faithful inspection; and the superintendent, as well as every inspector, is specially required to be anxiously attentive to the earliest appearance of injury from storms, which is instantly repaired, so as to keep open the communication until durable remedy can be applied.

Upon Highland roads, the bridges, cross-drains, breast-walls, parapets and retaining-walls being numerous and extensive, in proportion to the length of road, I found it advisable to employ working-masons as inspectors. These men, being paid by very moderate weekly wages, are encouraged to pass the greatest part of their time in perambulating the roads, by a mileage allowance for travelling expenses; and to obtain this, they produce journals of their daily movements; and it has been ascertained that Robert Garrow (the Argyllshire inspector) has travelled on foot 5,000 miles per annum. Luckily for these laborious men, who can scarcely be said to have a home, Mr. Rickman (Secretary to the Board) saw several of them on the roads in the year 1819, and observed that they suffered much from rheumatism, in consequence of their clothing being usually wet or damp, the smouldering fire of a Highland hut being of little efficacy for drying it, and their duty compelling them to be always on the roads in stormy weather. On his return to London, he sent them a piece of stout water-proof woollen cloth, and materials for making it into garments, suitable to each man's own convenience; and this was found to conduce so much to the health and efficiency of the inspectors, that the Commissioners directed the same allowance of cloth to be distributed among them every August,

at an expense of £. 29 per annum for the whole establishment. A superannuation fund has also been established for the benefit of those who may have been faithful inspectors, until disabled by old age or infirmity, towards which fund the public contribute £. 250 annually; and £. 20 a year for keeping a pony is now allowed to each inspector, conferring augmented power of activity and locomotion.

The discomforts attending the formation of new roads, in a mountainous and thinly-peopled district, cannot be duly appreciated by persons accustomed to usual accommodations; for not only was it difficult to procure and convey building materials for the bridges and other masonry,—but the workmen (for lodging or imperfect shelter in a variable climate) were obliged to construct temporary huts, the frequent removal of which created trouble and expense, and the going to and from them occupied much time, and fatigued the workmen to no purpose. To remedy this, military canvas tents were purchased, which were indeed easily removable from place to place as the road-work proceeded, but they were found too hot when each was occupied by ten or twelve men; so that, in rainy weather, they could not endure fires to cook their victuals, and dry themselves. Nor was it until the roads had been made generally passable by wheel carriages in 1824, that an effectual remedy could be introduced. This excellent contrivance (due to Mr. John Mitchell) consists of a large caravan on wheels, capable of containing sixteen or eighteen men, with a fire-place; it is movable from place to place by the Road Repair cart-horses, or even by the workmen themselves; and being always close at hand, much time is saved, fatigue avoided, and health uninjured. The cost of each caravan was about £. 30; the Commissioners paid one-half the price, the contractor paid the other half; he also kept it in repair; and in this manner he was encouraged to make offers, yet prevented from urging

extravagant demands; and it is gratifying to observe the combination of advantages afforded to all parties by this very simple contrivance.

With regard to the benefits derived by the Highlands from the works which I have thus enumerated and described, I shall insert in Appendix (L.) a letter written by the superintendent, Mr. Joseph Mitchell, addressed to the late Lord Colchester (who, as Speaker of the House of Commons, was for many years Chairman of the Board of Commissioners), his Lordship having made an extensive tour in Scotland in the year 1827, and being desirous of correct information of the state of the Highlands previous to the commencement of the improvements made under the authority of the Board, and the effects produced by the Parliamentary grants administered chiefly under his direction.

OF THE GLASGOW AND CARLISLE ROAD.

[*See* Plate 58.]

In the year 1814, the mail-coach road between Glasgow and Carlisle having become nearly impassable, not only was the Post Office intercourse occasionally impeded, but the general communication between the great manufacturing districts of the south-west of Scotland and the north-west of England was frequently interrupted, and at all times incommodious; for the mountainous districts through which a great proportion of the road passes being chiefly pasturage, it is only as a thoroughfare between the two extremities that the road is extensively beneficial.

Thus situated, the inhabitants of Glasgow and its vicinity (through Mr. Kirkman Finlay, their representative in Parliament) applied to Government, that a survey should be made by a person unconnected

with the district through which the road passes; and the Lords of the Treasury, having acceded to this request, were pleased to confide to me the requisite investigation. Having performed this accordingly, the necessary documents were submitted to a Committee of the House of Commons in 1815; which Committee, after full inquiry [*See* Report of Select Committee in Appendix (L.)], recommended that the plans described in my Report should be carried into effect, under the direction of the Commissioners for Highland Roads and Bridges, and in 1816 an Act of Parliament to this effect was passed.

The construction of the Glasgow and Carlisle road is very different from that of the Highland roads which have been described, the intercourse, in the present instance, being by the mail and other heavy coaches, and carts carrying from one to four tons; it was therefore necessary that the utmost care should be taken to make the working part, or middle of the road, substantial and firm, and the ascents regular and easy, seldom exceeding, at any place, one-thirtieth part of the longitudinal measurement of the road-way.

The former road between Glasgow and Carlisle was 102 miles; but, by sundry alterations suggested in my plan, this distance is shortened nine miles. The division between Glasgow and Hamilton, of eleven miles, was left in the hands of local trustees, as was the division of thirteen miles, at the boundary of the counties of Lanark and Dumfries, for which a separate Act had been previously obtained; so that the distance of 69 miles was now to be made, or effectually improved, under the direction of the Commissioners; and the whole, with some trifling exceptions, being constructed in an uniform manner, I shall insert a copy of the Specification of the Ninth Division, which may be considered as descriptive of the whole improved system of solid road-making, [Appendix (L.)]

Upon the 69 miles of road, owing to the mountainous nature of the district, the bridges are numerous, and of large dimensions:

Viz.—One Bridge of	3 arches	-	-	150 + 105 + 105 feet span
One ditto -	1 ditto	-	-	90 feet span.
Two ditto -	1 ditto	-	-	80 each ditto.
One ditto -	1 ditto	-	-	60 feet ditto.
Two ditto -	1 ditto	-	-	50 ditto.
One ditto -	2 ditto	-	-	45 ditto each.
One ditto -	1 ditto	-	-	40 ditto.
One ditto -	1 ditto	-	-	35 ditto.
One ditto -	3 ditto	-	-	30 ditto each.
Four ditto -	1 ditto	-		under 20 ditto.

Making 15 in all.

(For Fidler's Burn Bridge, and Johnstone Mill Bridge, *see* Plate 53.)
(For Birkwood Burn Bridge, and Hamilton Bridge, *see* Plate 54.)

I shall give three Specifications, which will sufficiently show the manner in which the bridges on this road are constructed [Appendix (L.)], and add, in the same Appendix, the height of the road at various points, and the quantity of materials and labour usually requisite for annual repair.

1. Bridge over the Avon, near Hamilton, of one arch, 80 feet span.
2. Bridge over the Dingle of Birkwood Burn, three arches, 30 feet span each, and 70 feet high.
3. Bridge over the river Clyde, near Crawford, one arch, 90 feet span.

This last bridge is situate at about half way between Glasgow and Carlisle, where the road enters the valley of the Annan, by passing down the narrow but direct valley of Evan-Water, and here crosses the Edinburgh road; this place was therefore selected as the proper situation for a good inn, which was accordingly built under my direction. This

became necessary, because the accommodation afforded to travellers at the town of Moffat was more than a mile distant from the new road.

The average expense of the road-making per mile, from £.800 to £.1,000, exclusive of the large bridges.

OF THE LANARKSHIRE ROADS.

[*See* Plate 58.]

It having been found that the most direct mail-coach road from Glasgow must be made so as to avoid the great bend which the river Clyde makes to the eastward, round Tintoe Hill, and by the town of Lanark, and instead thereof, to proceed by Douglas Mill, the extensive district on the north-east side of the river was left with unimproved and nearly impassable roads, which was peculiarly unfortunate, as the greatest body of limestone was at the northern boundary of the county, whereas the coal for converting it into lime lay at a distance to the southward, on the bank of the Clyde.

In the year 1820, when, from a great want of employment, the manufacturing population of these districts were in much distress, the principal inhabitants were induced to apply for a loan of Exchequer Bills, to be expended in making roads and bridges; and this being acceded to, and put under the same Board as the Glasgow and Carlisle road, the Commissioners directed me to make surveys, and prepare the necessary documents for two roads crossing each other at right angles, in the upper part of the county of Lanark.

The north and south line of road commences at Cumbernauld, and passing the large village of Airdrie, proceeds by Carluke and Lanark,

crossing the Clyde at Hyndford Bridge, and following the river round Tintoc Hill, terminates on the mail-road at Abingdon; its length being forty-one miles. This line forms a direct communication from the great cattle markets of Crief, Down and Falkirk, to Carlisle and the north of England. The east and west line, commencing at Brioch Water, at the termination of a new road from Edinburgh, proceeds by Allantown to Cambusnethan, where it crosses the north and south line, afterwards the river Clyde at Garrion Bridge, and then the Glasgow mail-road, near Stonehouse village; whence, passing through Strath-Avon, it terminates at Louden Hill; in all twenty-four miles in length.

Both these roads, in principle and details, are similar to the Glasgow road, only that the breadth between the fences is 30 instead of 32 feet, and the breadth of the stone metalling or workable part of the road is 15 instead of 16 feet; it is therefore only necessary to refer to the Specification already inserted, as regards Lowland road-making. As to bridges,—the north and south line, after leaving the town of Lanark, continues parallel with the bank of the Clyde to Carluke, and is carried over deep ravines by several lofty bridges,—and in like manner between Carluke and Cumbernauld; for the line, in coasting the river bank, is intersected by considerable streams near their junction with the Clyde: and the same difficulties occur upon the east and west line.

I shall insert drawings of the remarkable bridge at Cartland-Craigs (its middle arch 122 feet in height), and of the centering on which the three arches were turned; also of the toll-house near it. [Plates 55, 56, 57.]

All the bridges on both roads are built with excellent squared sandstone, of good quality, colour, and perfect workmanship; the Specifications are similar. I therefore only give that for Cander Water.

These two lines of road are now in a perfect state, and by them a commodious intercourse has been opened between all parts of the county of Lanark, and also with the upper part of the county of Ayr.

To persons who were in the habit of travelling in Lanarkshire, previous to these improvements, the change was surprising as well as gratifying; instead of roads cut into deep ruts through dangerous ravines, jolting the traveller, and injuring his carriage,—or leading him, if on horseback, plunging and staggering, circuitously over steep hills, the traveller has now smooth surfaces, with easy ascents, rendered safe by protecting fences. Such advantages, being equally beneficial to all ranks of society, are of the first importance in a civilized nation.

SCOTTISH HARBOURS.

No sooner were the Highland Roads and Bridges in good progress, under such direction as afforded confidence of the beneficial application of any funds entrusted to the same management, than further improvement of Scotland in general, and of the Highlands in particular, became an object of attention; and a Select Committee of the House of Commons was appointed to investigate the state of the funds arising from the forfeited estates in Scotland.

These estates were forfeited in consequence of the rebellion of 1745 in favour of the Stewart family, and were inalienably annexed to the Crown in the year 1752, the rents and profits thereof to be applied "for the better civilizing and improving the Highlands of Scotland;" and the rents were so applied until the year 1784, when the former Act of 1752 was repealed, and the estates re-granted to the heirs of the former proprietors, on certain conditions, one of which was, that they

should pay (or rather re-pay) to the Crown the amount of family incumbrances, which had been satisfied out of the rents between the years 1745 and 1784.

The sum so repaid exceeded £.90,000, of which £.15,000 was granted by the disannexing Act of 1784, for completing a repository of records at Edinburgh, and £.50,000 was advanced for completing the Forth and Clyde navigation. This last sum, having been repaid, was again lent in equal moieties; £.25,000 for the improvement of Leith Harbour; £.25,000 to the Crinan Canal Company.

Other sums of money, moderate in amount, had been expended, chiefly for Highland purposes; and the Committee, finding that about £.47,000 was disposable by Parliament, did not fail to recommend the improvement of fisheries, of agriculture, of harbours, of canals, and of sundry miscellaneous objects. Such large intentions were not likely to be realized from inadequate means, and in the sequel, £.12,000 was given for rebuilding the Court of Exchequer at Edinburgh (the Barons having had the forfeited estates in their custody); £.7,500 for the formation of a harbour at Wick; £.8,000 in the form of a conditional annuity to the Highland Society for agricultural improvement, and £.2,000 for building a lunatic asylum at Edinburgh. Thus about £.30,000 of the available funds was specially appropriated, and the actual residue, with the claims on the Leith Harbour and Crinan Canal Companies, was transferred by Act of Parliament, in the year 1806, to the Commissioners already appointed to make Roads and Bridges in the Highlands.

Those Commissioners did not feel themselves enabled to undertake much, upon receiving about £.13,000 in ready money, with reasons

why no more could then be paid to them; and they resolved to direct their attention to harbours, or (more properly speaking) to landing piers for ferries and the fisheries. But at the end of the war, the city of Edinburgh found it expedient to borrow money elsewhere, to pay off the entire Leith Harbour debt, whereby the Commissioners were enabled to extend aid to harbours of some importance. They had discovered the occasional inconvenience of advancing money to contractors, to enable them to commence roads or bridges; wherefore, to simplify their transactions in the harbour grants of aid, they issued a moiety of the estimated expense to the parties making application, leaving to them the care of engaging sub-contractors, and thereby also making them responsible for any excess of expense beyond the estimate.

The principal harbours improved in this manner were Peterhead, on which upwards of £.30,000 (one-half paid by the Commissioners) was thus expended; on Banff Harbour, £.16,000, in like manner; on Frazerburgh Harbour, about £.11,000; at Fortrose, at Cullen, and at Kirkwall, about £.4,000 each; on the whole, about £.110,000 was thus expended, by a careful application of about £.50,000, arising from the forfeited estate funds, which at first authorized little hope of this degree of useful application. The smaller objects of aid are best exhibited in a statement of the expenditure of the entire fund, which was exhausted in the year 1824. [*See* Appendix (L.)]

The claim on the Crinan Canal Company for a debt of £.25,000 was not available; so far from it, that, to prevent the ruin of that water communication (whereby the delay and danger of fishing-vessels in sailing round the Mull of Cantyre was obviated), the Legislature was induced to grant £.19,400, in the year 1816, which sum was effectually expended under my superintendence, in the year 1817, by Mr. John

Gibb, of Aberdeen, than whom, on this occasion and many others, I have never known a more active, zealous or respectable contractor.

I have illustrated, by several Plates, the foregoing description of the Caledonian Canal, of the Highland Roads, and of Bridges in Scotland; but the objects were so various and so numerous, that I must also be permitted to refer generally to the Reports of the respective Commissioners, especially to the Caledonian Canal Report of the year 1824, for a map of the Crinan Canal; and to the Highland Road Report of 1821, for plans and elevations of the largest Bridges on the Highland roads (all reduced to a uniform scale, for the sake of comparison); and for the landing piers, and the several Scottish harbour improvements, on another Plate.*

HIGHLAND CHURCHES.

[*See* Plate 58.]

I ought not to omit in this place the Highland Churches, for building which a Parliamentary grant of £.50,000 was given, in the year 1823, in reliance that the work might be conducted at moderate expense, although in scattered and remote situations, under the inspection of the same persons who had become conversant with local peculiarities, and might employ their experience beneficially for a purpose not dissimilar, in so far as regarded plans, contracts and inspection. I was called upon to furnish the plans and specifications, and to arrange the

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* By favour of the present Speaker of the House of Commons, 500 copies of these Plates of Bridges and Harbours have been printed for insertion in the Atlas annexed to this posthumous work of Mr. Telford; they are inserted [Plates 51, 52] in sequence with the other Plates.

first contracts; but I had little occasion to undertake personal superintendence, which was well performed by Mr. Joseph Mitchell in the northern counties, and by Mr. Robert Garrow (the most meritorious of our road inspectors) in Argyleshire.

I annex plans and elevations of the churches and manses [Plate 59], which were not permitted to exceed £.1,500 in expense at any one establishment. The manses were of one or two stories, according to the situation of the place, or the wish of the parties concerned. I also insert [Appendix (M.)] a list of the churches, with the several dates of the certificate of completion, which was required previously to the appointment of a minister; the last of them in the year 1830. The history and result of this grant "for building of additional places of worship in the Highlands and Islands of Scotland," cannot be summed up more perspicuously than in the words of the Commissioners:—"The liberality of the Legislature has been exercised in such a manner as rather to conceal than display its amount. The original grant of £.50,000, and about £.10,000 expended in general management, in legal conveyances of land, and in the superintendence of works locally remote and scattered, represent (on cursory inspection) the entire benefit conferred; but the religious services of forty-two additional ministers in perpetuity have not been obtained for less than £.5,040 per annum; that is, for a perpetual annuity, worth about £.120,000, which, with the above-mentioned grant and expenditure, amounts to no less than £.180,000 appropriated to the advancement of religion in the Highlands and Islands of Scotland." The number of persons which the churches are capable of containing, without inconvenience, is estimated at 22,000.

Conclusion.

Concerning Highland Roads and Bridges, my Survey was delivered to the Lords of the Treasury in 1802, and the Act constituting the Board of Commissioners was passed in 1803. For the Glasgow and Carlisle Road, the Report to the Treasury was made in 1815, and the Commissioners were charged with the management in 1816, and with that of the Lanarkshire Roads in 1820; so that the whole of Scotland, from its southern boundary, near Carlisle, to the northern extremity of Caithness, and from Aberdeenshire on the east to the Argyleshire islands on the west, has been intersected by roads; its largest rivers, and even inferior streams, crossed by bridges; and all this in the space of twenty-five years, under the same Board, and (with some few exceptions) by the same individual Commissioners. The names of these deserving persons, so long and so usefully employed, I embrace this opportunity of recording.

Names of the Commissioners.

Charles Abbot, Speaker of the House of Commons, afterwards Lord Colchester.

Nicholas Vansittart, Chancellor of the Exchequer, afterwards Lord Bexley.

Sir William Pulteney, Bart., M. P.

Hawkins Browne, Esq., M. P.

William Dundas, Esq., M. P.

Charles Grant, Esq., M. P.

William Smith, Esq., M. P.

The Secretary to the Commissioners was John Rickman, Esq. (afterwards First Clerk Assistant in the House of Commons), with whom,

during the time the works were in progress, rested the sole responsibility of receiving all communications and reports, and bringing them before the Board, recording their proceedings, regulating financial transactions, corresponding with the applicants and with the Board officers; and, in truth, it was on his able conduct, unwearied zeal and perseverance, that the entire success of the improvements chiefly depended.

The Law-Agent of the Commissioners at Edinburgh was James Hope, Esq., W. S., whose punctuality and attention in arranging pecuniary transactions with the contributors, preparing contracts, and making payments as the various works were prosecuted, were unremitting; and the result of his skill and integrity in managing the perplexities which arose out of such complicated transactions, without once having recourse to legal process, shows what may be accomplished by an upright professional man, whose only object is the good of all parties in a combined transaction.

The practical operations fell to my share; that is, preparing plans, sections, specifications and estimates for each particular work, assisting the law-agent in forming contracts, seeing that the lines of roads and situation of bridges were judiciously determined, selecting properly-qualified persons for general inspectors and superintendents, causing the works to be measured and certified monthly, and frequently examining and reporting the progress made, so as to enable the Secretary to bring the whole before the Board. This arduous task I have, by the aid of my able coadjutors, Messrs. Rickman and Hope, been enabled successfully to perform; and during the course of thirty years' operations, extending over 1,000 miles of new road, including 1,200 bridges, in a mountainous and stormy region, only five of which have required to be renewed, while occasional damages of the roads have been immaterial, and speedily remedied; and all things now remain in a perfect state.

Not a small portion of this ultimate success is due to the chief inspectors, Mr. John Mitchell in the Highland, and to Mr. John Pollock in the Lowland roads; the accurate execution of the various plans and specifications being attributable to their honest zeal and persevering anxiety. The former, as has been already stated, became the victim of over-exertions in a stormy climate; and that four out of five officers should have survived to enjoy the satisfaction of receiving unqualified approbation, is an occurrence seldom exemplified in the progress of human affairs. May it become an encouragement to others never to falter in arduous enterprises; for, considering the rude and remote districts in which the chief portion of these works were performed, the conflicting interests of the contributors, the obstacles which sometimes interrupt public aid, and the occasional perverseness of contractors,—it must be confessed that our progress was at times sufficiently perplexing, though never hopeless.

IMPROVEMENT OF THE OLD GLASGOW BRIDGE.

[*See* Plate 60.]

Having thus insisted at some length on what was performed under the Parliamentary Commissioners in Scotland, I shall, previous to leaving the western side of North Britain, describe a work of some novelty.

By degrees a very extensive suburb of the city of Glasgow has spread itself on the southern bank of the river Clyde, under the name of Trades Town, whence it became necessary to improve the means of intercourse across the river. The old bridge is substantial, but its breadth between the parapets was no more than twenty-two feet, including the footways. The building of a new bridge being precarious

and expensive, the magistrates consulted me whether it was practicable to give additional breadth of roadway on the old bridge.

Having procured an accurate plan and description of its then state, I found that the piers were sound, and that their points projected considerably in advance of the parapet and the face of the arches. This circumstance suggested to my mind, that a wider roadway might be obtained by means of a cast-iron addition to it; for which purpose, upon the pier-points I caused small pedestals to be constructed, projecting as much as the additional width required; upon these pedestals was supported a cast-iron rib over each arch, on both sides of the bridge, from which ribs cast-iron bearers rested fairly upon the masonry cornice, and were covered with large flat stones, which formed footpaths, protected by strong iron railing; and thus the whole body of the masonry bridge (23 feet) was appropriated to carriage-way, and a footpath, nearly six feet wide, was appended on each side, upon the attached iron-work [as represented in the Plate 60.] Thus improved, the bridge was rendered not only sufficiently commodious, but even ornamental; the external appearance having an air of originality and lightness by the projection of the iron-work, and the shadow thereby thrown upon the masonry below it.

GLASGOW BRIDGE.

[*See* Plate 61.]

At Glasgow, by deepening the river Clyde down to Dumbarton, vessels of 300 tons now come up to the Broomielaw, or city quay, from which it has become a busy port [Appendix, N. 1.], especially frequented by steam-boats, which may be said to have had their origin in the Clyde [Appendix, N. 2.], so that deepening was required close up to Jamaica-street Bridge; and as the foundations of this bridge

were not deep, and, in fact, placed on an ancient over-fall weir, there was risk of their being undermined; the road over it was also too narrow and steep for the increased intercourse between the city and new wharfs on the south side of the river. Under these circumstances, an Act was obtained for building a new bridge, for which I furnished a plan and specification [Appendix, N. 3.]; and the said bridge is now in progress, Mr. John Gibb being the contractor.

*Continuation, by Mr. Gibb.**

The increase of trade and population in the city of Glasgow and its adjacent districts having been such as to render the Jamaica-street or Broomielaw Bridge inadequate to its purposes, the trustees resolved to remove it, and to build in its stead a bridge which would offer more suitable accommodation, such as the increasing population of this large city and its suburbs required. Having obtained an Act of Parliament, they employed Mr. Telford, who, previously to furnishing a design for the bridge, appointed as resident engineer Mr. Charles Atherton, who had previously been employed under Mr. Telford, in the same capacity, at the Dean Bridge of Edinburgh, where also the same contractors were employed, and instructed him to make the necessary borings. This having been accomplished, by the aid of cast-iron cylinders, to the depth of 70 feet, the whole was found to be a body of sand, of rather an adhesive texture, but such as rendered it necessary to construct the entire foundation on bearing-piles, driven, on an average, to a depth of 15 feet, and surrounded by a row of Sheeting-piles, with cross sills,†

* The reader, who has already seen, in the instance of the extensive harbour improvements at Aberdeen, that Mr. Telford introduces Mr. Gibb's Narrative into the text, will recognize him with pleasure in this supplementary Report of his progress in the Glasgow Bridge, after Mr. Telford's death.—This bridge is not the only instance in which the energy of Mr. Gibb has overtaken the stipulations of his contract.

† *Sills*; *q. d.* door-sills, lock-gate sills: (sometimes spelled *Cills*, but inconveniently, because the last is similar to a word often useful in natural history.) *Sills*, in bridge-building, are squared timbers, bolted on the head of the piles, which are thereby firmly

the interstices filled with concrete, and the top of the piles covered with two tiers of three-inch planking.

The design and specification having been prepared, the work was advertised for contract, and Messrs. John Gibb and Son, of Aberdeen, became the successful contractors. On the 18th of March 1833, the contractors obtained liberty to proceed, but for some time with the south abutment only, the cofferdam of which was in progress on the 1st of April. On the 8th of July, the timber-work of the foundations (as already described) of the south abutment was completed, and the first stone of the foundation-course laid, at the depth of 18 feet below high-water mark ; that is, 12 feet deeper than the foundation of the old bridge, for the purpose of allowing the removal of the weir on which it was built, and which impeded the current of the flowing tide, and prevented navigation upwards. On the 2d of August, the timber-work of the foundation of the southernmost pier was completed, and the masonry founded at the same level as that of the south abutment. On the 3d of September the honorary foundation-stone was laid, with due ceremony, in the south abutment, by James Ewing, Esq., M. P., and Lord Provost of the city, assisted by numerous masonic lodges, the masonry surface being then ready to receive the springers (or first course) of the arch-stones. By the end of 1833, the three southernmost piers were also built up to the springing.

During the year 1834, the north abutment, and the three piers or pillars next it, were built ready for the springing of the arches ; all the cofferdam timbers were drawn out, and the four centerings requisite for the arch-building were framed and ready for setting up.

connected ; and on which planks for receiving the foundation-masonry are fixed with spike-nails, driven through the planking into these sills.

On the 2d of April 1835, the contractors began to turn the arches; and by the 1st of December the contract was completed, the work being taken off the contractors' hands on the 9th of December; and on the 1st of January 1836, the bridge was opened to the public by the Lord Provost, accompanied by the trustees and other public authorities. Thus this large bridge, which was not expected to be in use earlier than four years from its commencement, was completed in two years and eight months, being eighteen months within the time allowed by the contract.

The bridge consists of seven arches, being circular segments, of the following dimensions:—The span of the centre arch is 58 feet 6 inches; its rise, 10 feet 9 inches; the span of each arch adjoining the centre arch, 57 feet 9 inches; its rise, 10 feet 6 inches; the span of each arch adjoining the abutment arches, 55 feet 6 inches, and its rise 9 feet 8 inches; the span of each of the abutment arches, 52 feet; its rise, 8 feet 3 inches. The breadth of open waterway is consequently 389 feet; but the entire length of the bridge, from centre to centre of newals,* is 560 feet. The width of the carriage-way is 34 feet, which, with a footpath of 12 feet on each side, makes the total width of the bridge 60 feet; being wider, therefore, than any river-bridge in the kingdom, the new London bridge being no more than 56 feet.

The whole of the outer face of the bridge is built of granite, finely hewn or axed, the parapet being a balustrade of the same material.

* *Newals*, or *Newels*, are pilasters, which form the extremities of the wing-walls of a bridge; the top of them, therefore, supporting the commencement of the parapet. This word, in its strict acceptation, denotes the cylinder around which is built a circular or corkscrew staircase, the cylinder itself being formed by the inner ends of the stairs, superimposed as the work ascends. Hence the turret at the angle of a square church-tower, containing a newel staircase, is sometimes denominated a newel; its exterior projecting from the angle of the tower, as the newel here mentioned projects from the wing-wall end of a bridge.

The granite was all prepared by the contractors at Aberdeen, and conveyed to Glasgow in a state ready for position in the work.

The total cost of the bridge (exclusive of the approaches, and making the streets suitable beyond the extremity of each wing, and also of the engineering and superintendence) was £.34,427. 18*s*. No alteration of any moment was made from the designs furnished by the late lamented engineer, with the exception of a balustrade being substituted for a close parapet; the entire elevation and plan as designed by Mr. Telford, having been found admirably well adapted to fulfil his original intentions. The bridge-trustees concerned were so well pleased with the execution of this splendid structure, that they presented to the contractors two elegant pieces of plate, in testimony of the high sense they entertained of their zeal and fidelity.

THE DEAN BRIDGE, AT EDINBURGH.

[*See* Plate 62.]

On the eastern side of Scotland, two bridges of considerable magnitude are building from my designs; and as they will probably be completed before the publication of this work, I shall give a short account of them.

The city of Edinburgh having, of late years, extended greatly in all directions, but more especially on the north side, the face of the declivity between Queen-street and the Water of Leith has been occupied by new streets, squares and crescents.

At the north-west extremity, Moray Place, a polygonal square, stands on the very edge of a deep ravine, at the bottom of which the

Water of Leith passes between bold, rocky and finely-wooded banks. For a considerable distance westward from Moray Place, buildings have been extended along the southern bank; but the above-mentioned ravine intercepts their progress. But speculation was, however, not to be so limited; the land on the north bank was feued (leased in perpetuity) for buildings, on condition that the projectors should construct a proper bridge across the ravine. This was essential to the success of their scheme, in order to establish a communication with Moray Place and Charlotte Square; and a further inducement existed in obtaining an improved entrance into the city by the great north road, from the Queensferry: the trustees of which road, therefore, agreed to contribute a sum of money, on condition that there should be no toll on the intended bridge.

These arrangements being made, the projectors procured designs from two Edinburgh artists; but neither of these obtaining approbation, after much discussion, the road trustees objected to paying their share of the expense, unless the plan were furnished by me; whereupon, as the work was of considerable magnitude, and subject to casualties, I declined entering upon the business unless the several parties interested signed a missive letter, stating that my plan should be adopted, and the bridge built under my direction. These preliminaries being settled, I furnished a plan, elevation and section, with detailed specifications; and a contract was entered into with Mr. John Gibb, of Aberdeen, the same experienced builder whom I have before had occasion to mention with due commendation. The arches are 90 feet in span, and the edifice 106 feet in height from the bed of the river to the surface of the roadway; the breadth of the carriage-way 23 feet, with a footpath on each side of 8 feet; so that the whole breadth between the parapets is 39 feet; the total length is 447 feet. My design originally consisted

of three arches, but on commencing the excavation for the foundations on the south side, the rocks were found to be so much dislocated that no security could be obtained but at the risk of disturbing the face of the bank, as had happened under a part of Moray Place; prudence, therefore, induced me to change the design into four arches, of 90 feet span each, whereby the south abutment is placed upon solid rock, still preserving a degree of uniformity with the abutment on the north side. The piers are 31 feet in length (eight feet more than the breadth of the carriage-way over them) built internally with hollow compartments; the side-walls are three feet in thickness; the cross-walls two feet. Projecting from the piers and abutments are pilasters of solid masonry. The main arches have their springing at 70 feet from the foundations, and rise 30 feet; and at 20 feet higher, other arches, of 96 feet span and 10 feet rise, are constructed, and the face of these, projecting before the main arches and spandrils, produces a distinct external soffit of five feet in breadth; and this, with the peculiar piers, are the distinguishing features of this bridge. Inside the external spandrils are longitudinal walls, and the interstices are covered with flat stones, to support the roadway. The whole of the masonry of this bridge consists of square sandstone, of excellent quality, and its dimensions and form are distinctly shown in the Plates [Nos. 62, 63].

This bridge was built under the superintendence of Mr. Charles Atherton, who was employed under me, and assiduously performed his duty. He has furnished to the Encyclopædia Britannica a detailed narrative of the progress and completion of this bridge, from which the following description thereof is extracted:—

" Many practical advantages attend the construction of hollow piers; hereby no part of the masonry which, if the pillar was solid,

would tend in the least degree to its effective stability, is omitted; and by this method the bed of every stone throughout the work is exposed to view, which ensures perfect workmanship; and the saving of so much materials and labour is moreover an important consideration.

"In dressing the ashler (or squared stone) required to carry a heavy load, pains must be taken that the stones be as full at the back as the front, the workmen finding it to their advantage to slap away the back lean-to-the-square.* To this vicious practice, and consequently unequal bearing when set, the skirping* and even bulging of walls may generally be attributed; and therefore it was found advisable to specify that drafts* be put along the back part of the beds* of the ashler for the three-feet walls, and thus all skirps of the high piers and pilasters of the Dean Bridge were prevented."

* Such a deviation from the true square the workmen know to be an error on the *safe side* (with regard to themselves), as being unseen, and hidden in the masonry; whereas, deviation of the same kind under or over the intended face of the stone would certainly be perceived by a wider mortar-joint, or by the over-hanging, untrue perpendicular of the stone in the face of the wall,—and therefore not to be hazarded. A true rectangle at the back of each stone cannot be enforced, unless by the personal attention of the superintendent, who thus only can ensure accuracy of workmanship in the masons employed. —*Lean-to-the-square* is a fault, in consequence of the said *slapping away*, with the mason's hammer, the under-part of the stone behind, which makes it *lean-to-the-square*, or form less than a right angle with the face of the wall.—*Skirping*, and *bulging*, is a further ill consequence of the same bad practice of masons not duly watched in settling every stone properly on its bed; so that skirping, or chipping, may be defined an irregular fracture of the horizontal joints of masonry. This is consequent (but not till too late for remedy) on the slapping away, which ill-conducted workmen conceal by a substitution of mortar and stone-chips; but when great weight is imposed in the progress of the structure, this feeble substitute for solid masonry subsides more than the face of each stone, and thereby produces skirping. This unequal settlement is sometimes so great as to create a *bulging*, or outward curvature of the face of the wall, or even of the entire fabrick.—*Drafts* are channels made with a chisel on each unfinished stone, so as to regulate its upper and under surfaces (called *beds* of the stone), thus indicating bounds for keeping the beds full throughout; these drafts are worked accurately to the square from off the face of the stone (at right angles from the face of the stone); the upper as well as the under bed of the stone being reduced or worked off, true to the chisel draft; in the language of masons, neither too *full*, nor too *lean*.

It remains to be explained by what method the ascititious or external arches were executed, so as to allow of their subsiding freely upon the centering, without obstruction from the lower spandril-walls [Plate 63]; for it being evident, had the centres of the main arches been struck, and their spandrils completed close up to the soffit of the upper or external arches, these would, upon their centres being subsequently removed, have been subject to unequal depression; for if the interior three feet two inches of the soffit had rested upon the lower spandril-walls of the main arches, while the projecting five feet were left to subside freely, an unequal subsidence would have disturbed the entire superstructure; and it is equally evident, that the lower and upper arches (the main arches and external arches), being dissimilar, would not subside equally, and therefore their centering could not be struck at the same time, leaving them dependent on each other. The course therefore pursued was, by striking the centres of the lower arches as soon as the arch-stones were laid, and immediately proceeding in like manner with the turning of the upper arches, and also striking their centres previously to the completion of the lower spandrils. This was a delicate operation, and is understood to have been unprecedented; for the pillars, or rather pilasters, of the upper or external arches being only five feet wide, it follows that the four upper arches of 96 feet span each were supported solely upon their pilasters of five feet projection from the main piers, and five feet wide, being only one-nineteenth part of the arch-span. To accomplish this, it was evidently necessary that all the four arches should be struck as gradually and equally as possible, never allowing the slack-blocks* to be driven out more at one time than sufficient

* An apparatus whereby a slight upper centering is made to support the several arch-stones, as placed by the mason; after which, the sinking of the same stones by their own gravity is regulated at the discretion of the architect, by gradually withdrawing those slack-blocks, which are shaped properly for this important purpose.

to let down the centre a quarter of an inch. It was found that these external arches subsided equally and gradually, during a month, by which time they had acquired permanent stability, and their total subsidence amounted to four inches and a half at the crown, while the lower or main arches subsided about three inches at the crown. In constructing the centre, a subsidence of three inches had been calculated upon for the main arches, and six inches for the external arches.

After having allowed the external arches to attain permanent stability, a portion of their spandril-wall was built, and the centering removed, and the masonry of the lower spandrils was then made good up to their soffits. In completing the exterior spandrils (those of the external arches), which are only eighteen inches thick, they were connected with the interior spandrils by means of dove-tailed bond-stones, which, at the same time they gave stiffness to the walls, effectually tied them to the interior work, rendering the off-sets or wings and main body of the bridge a perfectly connected mass.

In all extensive edifices composed of heavy materials, it is of primary importance that arrangements be made, whereby every stone may be laid or removed with facility, by means of cranes, or other mechanical contrivances; a point which cannot be too forcibly insisted on,—for it will frequently be found, upon settling a stone in its place, that its bed is too full or too lean, or that from some other cause, the stone must be lifted, examined and re-set. If this can be readily done, the fault will be rectified; but if this operation creates much trouble, the masons will slight it, and the work will, of course, remain imperfect. The entire success which attended the execution of the Dean Bridge, and the expedition with which the work was carried on, are in a great measure

attributable to the judicious manner in which the machinery and scaffolding were constructed.

The bridge was commenced in October 1829, and completed (with the exception of the parapets) in December 1831, without any accident whatever,—the cost thereof being £. 18,556, exclusive of making roads of approach.

OF PATH-HEAD BRIDGE.

[*See* Plate 64.]

The other bridge to which I have alluded forms a passage over a ravine about eleven miles south from Edinburgh, at the village of Path-head. I had formerly surveyed a line of road from Newcastle, by Wooller and Coldstream, to Path-head, showing, that between Morpeth and Edinburgh, a mail-coach road, about fourteen miles shorter than that passing by Berwick, may be obtained. I had terminated my survey at Path-head, considering that, from thence to Edinburgh, the country was sufficiently rich and populous to improve these eleven miles; but although the inhabitants could well afford to make the road, they were prevented, by clashing interests, from agreeing on the particular line of direction. The trustees, therefore, requested Government to direct their engineer to make a survey, and determine what ought to be done; for which purpose I received instructions from the General Post Office on the 19th March 1827. I performed this service, and furnished designs for improving the road from Path-head through Dalkeith to Edinburgh. The most expensive portion of the improvement being the first mile north of Path-head, it was fortunate that the residence of one, the most zealous and active of the road trustees, Sir J. H. Dalrymple, Bart., was there situate. He lost no time

in making arrangements for commencing practical operations, and I immediately prepared working drawings and specifications for the first mile from Path-head, in which were included the ravines of Tyne-Water, Cranston-Dean and Cotty-Burn. The first is by much the largest, and the descent from the village being steep, the bridge is accordingly very lofty.

It consists of five arches, each 50 feet in span, and 25 feet rise from their springing, which is at 49 feet above the bed of the river; the shaft of each pier is 8 feet in thickness, and it is not solid masonry, the side and cross-walls being 2 feet in thickness; the longitudinal section of each shaft or pier, across the bridge, is 24 feet, with projections of 2 feet (at each end) 4 feet broad, at 19 feet above the springing of the main arches, and showing an equal breadth of soffit. The finished driving-way is 22 feet in width, with a footpath on each side of 2 feet, making the width between the parapets 26 feet; and, with the exception of the backing of the outer and cross-walls in the abutments, the whole bridge consists of square sand-stone. As all the forms and dimensions are shown [in Plate 63], I shall avoid further details, and only state that the bridge has been completed, and answers its purpose, having now been in use during several years.

MORPETH BRIDGE.

[Plate 65.]

The general improvements pointed out in my Survey in Scotland, south of Edinburgh (that is, between Path-head and Coldstream), have proceeded with considerable energy; and in England, the rugged districts south of the Tweed, between Wooller and Morpeth, are now likely to obtain a good road.

At the town of Morpeth, in consequence of fatal accidents, the General Post Office indicted the bridge, and the parties interested were under the necessity of rebuilding it in a manner adequate to the passage of numerous wheel-carriages on this great north road. Under these circumstances, I furnished the plan and estimate, and an Act of Parliament was obtained. In order to preserve the intercourse through the town, the approaches on both sides being on low ground, there was a necessity for placing the roadway on the lowest practicable level; and there is also a mill on the lower side of the north abutment requiring attention. These circumstances rendered it impossible to introduce an edifice of much magnificence; utility was therefore all that could be attempted. The bridge consists of three arches, of which the two side-arches are 40 feet each, and the middle arch 50 feet in span, with a rise of 18 feet 6 inches; the carriage-way is 22 feet wide, with a footpath on each side, making the breadth between the parapets 30 feet. This improvement will remain equally valuable, whether the mail-coach road passes by Berwick or Coldstream. But on this great north road, besides what has been noticed, much improvement is still required, as at Newcastle, and through the counties of Durham and York, and indeed all the way to London, to render the road suitable to the increased intercourse; and that this may be effectually accomplished is shown by the Surveys and Reports made by me for the General Post Office, and of which I propose to give a general description in a subsequent part of this work.

HOLYHEAD ROAD AND PACKET HARBOURS.

Having thus discussed, at some length, the several improvements made under my direction in Scotland, and having alluded generally to

the Surveys made through the eastern counties of England, I have now to draw the attention of my readers to the numerous and extensive improvements made on the direct line of communication between London and Dublin. At the time of the Union of Great Britain with Ireland, in the beginning of the present century, the principal lines of communication between the two islands were as follows:—(1.) By Milford Haven and Waterford, on the south;—(2.) By Holyhead and Dublin, in the middle;—(3.) By Portpatrick and Donaghadee, to the northern part of Ireland; and of these the middle, being the most direct between the two capitals, has always hitherto been most frequented; but as a general thoroughfare, its state, until the year 1815, was very imperfect.

On the Irish side of the Channel, the landing-place was within the bar of the river Liffey, always inconvenient, not unfrequently dangerous; and in crossing the Channel from Dublin (about twenty leagues), the sailing-packets then employed were occasionally tossed for several days in a stormy sea. When arrived on the English side, the passengers were landed upon rugged, unprotected rocks, at Holyhead; from whence the miserable tracks of road presented a succession of circuitous and craggy inequalities for twenty-four miles, across the island of Anglesea, to the Menai Strait, then passable only by a troublesome and dangerous tidal ferry. From thence through North Wales, the road was, generally speaking, narrow, steep, and unprotected by parapets; and even after reaching smoother ground, the mail-coach road to London (180 miles) was in a very imperfect state.

Under these circumstances, public business was impeded, and the Irish Members of Parliament suffered much personal inconvenience in attending their duties in London, and in resorting, at Easter, as magistrates, to their respective counties in Ireland.

This being dreaded, if not experienced, by all, gave occasion to grievous complaints, so that Government was obliged to consider of some means to remove the aforesaid obstructions. The packet landing-places on each side the Channel were first examined; and in the years 1801 and 1802, Mr. Rennie, an eminent engineer, was employed to make surveys and reports upon the most eligible situations for packet-stations, and the expense of constructing them. This service he performed, and with the assistance of Captain Joseph Huddart, an experienced navigator, determined that Holyhead in Anglesea, and Howth (north of Dublin Bay), were the most suitable; so that in 1808 a sum of £. 10,000 was granted by Parliament for the commencement of operations.

From that time, these two improvements were regularly carried on under that able and experienced man, until his death in 1821; since which they have (as part of the general communication between London and Dublin) fallen under my charge; and on that account, although the general outlines were nearly completed, I have given plans of them [in Plates 79, 80], showing a protecting pier and graving-dock, also sundry other works which have been constructed under my direction at Holyhead. But the formation of roads has been my chief occupation; also inclosing the harbour at Holyhead, and deepening the entrance and packet-stations at Howth; which operations have not only rendered the harbours commodious for steam-packets, but useful asylums for coasting and fishing vessels.

While these landing-places were in progress, the navigation of vessels in a tideway, by means of steam-power, was brought to a considerable degree of perfection. It sprung from an experiment made on the river Clyde, in the year 1811, by the ingenious Henry Bell, with a small

steam-boat engine of four-horse power, for carrying passengers from the city of Glasgow to the baths which he had constructed at Helensburgh, opposite Greenock, [but *see* Appendix, O.]; and this new and singularly useful mode of propelling vessels was in a short time extended from the Clyde to almost every estuary around the British isles, and, by degrees, to the passage between Holyhead and Howth,—and combined with the improved landing-places, renders the passage across the Irish Channel as regular and rapid, and almost as safe, as a mail-coach upon a good road; so that, between London and Dublin, one uniform rate of travelling may now be safely assumed.

After crossing the Channel from Dublin, the Menai Strait, which separates Anglesea from Carnarvonshire, was the most serious obstacle; because, from the weather being often boisterous, the mail and other coaches were not passed over, so that all the passengers had to collect their luggage, which, with themselves, was then exposed in an open ferry-boat, frequently in stormy weather, and very often during the night. This was, indeed, a just ground of complaint, and Mr. Rennie designed a plan for crossing this strait by an iron bridge; but the estimated expense, added to that of the harbours, was considered too much to be asked at one time, and therefore this plan was not carried into effect.

The frequent journeys made by the Irish members produced constant irritation and complaint respecting the road through North Wales, and gave rise to warm discussions in Parliament, so that, at last, a Committee was appointed to investigate the subject; but no satisfactory information was obtained, until Mr. John Foster (afterwards Lord Oriel), at that time Chancellor of the Irish Exchequer, took the matter in hand, and, by authority of Government, employed me to make a complete survey between Holyhead and Shrewsbury, also between Bangor and

Chester, and to report as to the best line in which a perfect mail-coach road could be made, and at what expense. Thus authorized by instructions, dated the 4th of May 1810, I completed extensive surveys, and made my Report to the Lords of the Treasury on the 22d of April 1811.

The district through which the surveys were carried is mountainous, and I found the existing roads very imperfect. The principal object in view being an improved road between London and Dublin, the leading consideration was, whether the distance between Shrewsbury and Holyhead could be lessened, and rendered more commodious and safe.

In a mountainous region, the points to be attended to are,—(1.) The direction and shape of the valleys;—(2.) The comparative heights of the several passes in the ridges between them;—and, (3.) The obstacles of rivers and sea-inlets.

The two principal valleys in this district are occupied by the rivers Dee and Conway. Both of these rivers deviate very considerably from a strait line between Shrewsbury, Bangor and Holyhead; and between the valley of the Severn and that of the Dee, I made three attempts to cross the Borewyn ridge, which separates them, but found the lowest pass 1,000 feet above Corwen Bridge, and that the two others were respectively 1,100 and 1,200 above the same place; whereas, from Corwen there is a regular descent of 122 feet to the summit of the Ellesmere Canal, where the open country commences; it therefore became necessary to proceed from the English plains, where the river Dee leaves the mountains, at the bottom of the valley of Llangollen, and from thence to ascend along the south side of that river to the town of Corwen. At this place the tributary stream of the Gairw,

coming from the westward, forms a valley, up which the road passes to its summit, at Cairneoge Mawr. Beyond an excellent inn at this place commences the Conway valley, descending westward and north, and formerly containing a line of road to the ancient town of Conway; from whence, after crossing the steep hill of Sychnant, at 543 feet above the sea, and also the rugged promontory of Penmanmawr, the traveller proceeded along the shore to the city of Bangor; but several years previously to my survey, the track of a new mail-coach line had been marked up the valley of the Lugwy, by Capel-Cerrig to Lake Ogwen, and down a river of that name to Bangor, by which a considerable distance was saved.

Although it was not possible to depart from the before-mentioned valleys, yet numerous minor improvements were found practicable, so that many steep hills were either avoided, or rendered of easier access, and the road was not unfrequently changed to a better exposure on the opposite side of the valley; across the island of Anglesea, indeed, the old line was totally abandoned.

In order to show the state of the old road through North Wales, and likewise the proposed variations, I caused accurate maps and sections to be made of the existing and also of the intended road, upon the same scale, by which they were fairly brought into comparison, and the necessity for improvements rendered manifest.

By reference to these maps and sections laid before the Committee of the House of Commons, it was evident that the old road was hilly and crooked, with ascents of one in 6½, 7, 8, 9, 10, 11, 12, 13, 14, 15;*

* One foot ascent in six-and-a-half, seven, eight, &c. feet longitudinal measure of the roadway.

frequently not more than 12 or 13 feet in width, and passing along the edge of unprotected precipices; in fact, quite unfit for wheel-carriages: so that the Committee to whom my Report was referred (several of whom personally vouched for its correctness) had no hesitation in reporting to the House, in the strongest terms, on the necessity which existed for carrying all the proposed improvements into effect.

But from the 30th of May 1811 (when this Committee made their Report) until May 1815, no practical measures were adopted; the office of Chancellor of the Irish Exchequer was abolished, and Mr. Foster, now become Lord Oriel (who had first patronized the road improvement), had retired into private life. The demand, indeed, for improvement remained equally urgent, but no one undertook the arduous task of arranging a practical scheme, until in Sir Henry Parnell (then Member of Parliament for Queen's County) was found a degree of intelligence, zeal and perseverance which overcame every obstacle. By recommendation of a Committee, of which he was Chairman, a Board of Parliamentary Commissioners was appointed; the necessary surveys and estimates were made under their direction; the aids granted by Parliament were administered through them, the contracts and payments being made immediately under their control; and the works were performed under the inspection of officers of their appointment; while the Commissioners were themselves responsible to Parliament, and made annual reports.

Under these Holyhead Road Commissioners, it was my duty, as their engineer, to arrange, direct and superintend all practical operations. I had one principal assistant between London and Shrewsbury (153 miles), and another between Shrewsbury and Holyhead (107 miles); besides whom, in the latter district, which was wholly under the management of the Commissioners), four inspectors were also employed;

but as the portion of road in England remained (with the exception of the new improvements) in the hands of the turnpike trustees, only occasional inspectors were necessary. All the works in both districts were performed by contract.

The road through North Wales being in many places almost impassable, the most dangerous portions of it were selected, and the improvements were performed under the following regulations:—

(1.) Working drawings, specifications and estimates were prepared by me, describing in detail all that was to be performed under each contract.

(2.) Advertisements were inserted in the newspapers, inviting persons experienced in road-making to transmit proposals to the Secretary of the Board; stating also where the plans and specifications might be seen, and where persons were stationed to show the ground.

(3.) The Commissioners accepted the lowest tender, if supported by character and security.

(4.) The works were performed under inspectors nominated by me, and approved by the Board.

(5.) The works contracted for were measured monthly, and the progress certified by the inspector, whose certificate, countersigned by me, was transmitted to the Secretary, who authorized the contractor to draw nine-tenths of the amount; the remaining one-tenth was retained in the hands of the Commissioners, as security for due performance of the contract.

(6.) When the contract was certified to have been completed, the balance was paid within two months, with interest upon the sums retained.

In case of particularly difficult operations, I was permitted previously to fix the prices of the works, and select experienced contractors. Acting under these arrangements, every operation was pursued with energy; and by the year 1819, many of the most dangerous portions were rendered commodious and safe; so that, in my Report of the 30th of June of that year, the following improvements in North Wales were stated to be nearly or quite complete:—

	Miles.	Yards.
(1.)—Between Bangor Ferry and the Town of Bangor - -	1	1,188
(2.)—At Llandegai, an angle cut off - - - - - -	–	1,435
(3.)—From Ty-Gwm to west of Lake Ogwen - - -	1	1,094
(4.)—Near the Great Waterfall of the Llugwy - - -	1	1,133
(5.)—From Bettws-y-Coed, up Dinas-Hill, to Rhydllanfair -	3	1,166
(6.)—Up a rugged pass at Glyn-Conway - - - - -	–	946
(7.)—At Cerig-y-Druidion, an angle cut off, and a hill avoided	–	780
(8.)—Between the two Bridges over the Gairw - - -	1	592
(9.)—The rocky pass at Glyn-Dyffrws, and road along the north side of the valley, including a bridge of 60 feet span -	2	731
(10.)—East of the town of Corwen, at Owen Glyndwr's Hill -	–	984
(11.)—From near Llandegai, across the river Ogwen, and to near the slate quarries, with a bridge of 60 feet - -	4	438
(12.)—A new road on both sides, and over the Rhys-gog Hills -	2	379
(13.)—From the east end of Lake Ogwen to opposite Capel Ceriog - - - - - - - - - - -	4	314
(14.)—From the toll-bar at Capel-Ceriog, down the north side of the valley, and across the Llugwy - - -	1	1,400
	27	260

When such progress had been made as to admit of a considerable distance being travelled with facility and safety, it occurred to me, from what had taken place in the Highland roads, that much risk of neglect would be incurred if the newly-made roads in North Wales were left in the hands of the local turnpike trustees; and being confirmed in this opinion by persons thoroughly acquainted with the former conduct of these trustees, I suggested the propriety of consolidating the seven trusts between Shrewsbury and Holyhead, and vesting the sole management in the Parliamentary Commissioners. This proposal, after due

investigation, was adopted, and in 1819 an Act was obtained, authorizing them, upon payment of debts which had been incurred in the feeble efforts made in forming a mail road by Capel-Ceriog, to receive and apply the tolls.

In North Wales, the new road-making was conducted after the same manner as the Glasgow and Carlisle road, except that the masonry of the bridge, breast and fence-walls, and also the cross-drains, instead of sandstone, were almost uniformly built of schistus, or slate rubble-work. The largest bridges were of iron, resting on stone abutments [*see* Plate 69]; and to ensure a durable road, the bottom, after being properly formed, was paved with schistus, or other rough stones, carefully set on edge, to the depth of six or seven inches. Upon this was placed a layer of broken stone (called, in road-making, top-metal), to the depth of five and seven inches, consisting of basalt, porphyry, limestone, or indurated grawacke; the hardest material, in fact, which could be procured in the vicinity; and this was frequently a difficult task, as the rocks in North Wales are generally of the schistus family, unfit for top-metal. Over this was laid a very thin coat of binding gravel, merely to smooth the surface, in order that it might be travelled on equally. I insert the heights of road at the various summits, from Holyhead to the vicinity of London [Appendix (O.)]; also, copy of a specification for the road-making, which was occasionally varied, on account of localities; and also insert [Plate 66] Road-making, represented by cross-sections;—[Plate 67], Section of a Polish road, and road-making tools;—and [Plate 68] toll-houses, toll-gate and milestones, on the Holyhead road.

In this session of Parliament (1819), an Act was obtained for constructing a bridge across the Menai Strait, and making a new road of

21¾ miles in length across the Island of Anglesea, agreeably to plans and surveys already prepared, and these have been completed,—the road in the manner already described. But as the Menai Bridge is a work of great magnitude and novelty, that and others on this road, as well as the harbours, demand full details, which, in order to avoid interruption of the narrative, I shall for the present postpone.

This road, established through a rugged and mountainous district, partly along the slope of rocky precipices, and across inlets of the sea, where the mail and other coaches are now enabled to travel at the rate of nine or ten miles an hour, was indeed an arduous undertaking, which occupied fifteen years of incessant exertion.

Two of the most arduous operations in North Wales were embankments across arms of the sea; one across an inlet or small estuary near Holyhead, called Stanley Sands; the other forming the eastern approach to Conway Bridge and Castle.

The embankment over Stanley Sands, near Holyhead, is 1,300 yards in length, and 16 feet in height, and the top, including the roadway and parapets, is in width 34 feet. The slope towards the sea is three horizontal to one perpendicular, and on the other side at the rate of two to one; the breadth of the base is 114 feet: both sides are coated with rubble-stone, which has proved an effectual protection against the most violent storms. Fortunately, in one spot occurred a rock-foundation of sufficient dimensions to receive an arch, which was necessary to admit the flood-tide to cover the space to the westward of the mound. This new road saves one mile and a half in the distance of six miles. This embankment was, by the unexampled exertions of the contractors, Messrs. Gill and Hodges, completed in one season; and the new road over it was opened in 1823.

For the eastern approach to Conway Bridge, the embankment is 666 yards in length; the breadth at the top is 30 feet; its greatest height is 54 feet; the slope on the sea-side is three horizontal to one perpendicular; on the other side it is two to one; the greatest breadth at the bottom is 300 feet. As the tide flows ten miles above the site of this embankment, the velocity of the current was so much increased upwards and downwards, when it was two-thirds advanced, that the gravel and earth was swept away to the depth of 54 feet, where was a bottom of hard clay and rock, and it was with difficulty the newly-brought materials were retained; nor indeed was it accomplished but by sinking a casing of rubble-stone at the outward extremity of the base on the seaward side. By persevering in this mode, the mound of approach was completed, and protected by a rubble-coating, in the year 1825; and on my inspection in 1834, it remained in a perfect state.

On the line of communication between Conway and Chester, four important improvements have been effected, under the authority of the Parliamentary Commissioners:—

1. From Ogwen Bridge, at Penrhyn Park, to avoid Tally-Pont Hill.
2. Along the rugged skirts of the huge Pen-man-Mawr, where the road was formerly steep, narrow, and unprotected from precipices.
3. Around the base of Pen-man-Bach, on a level to the town of Conway, whereby the former roadway, over the steep hill of Sychnant (543 feet above the sea), is avoided.
4. A new road, to ease the ascent of Rhyall Hill, between St. Asaph and Holywell.

Other dangerous hills on this road still require improvement, particularly Pen-man-Rhos, a little west of Abergelè.

On the Irish side of the Channel, between the landing-place at Howth and the city of Dublin, was a very imperfect road, which, under the authority of the Commissioners, has been rendered in all respects equal to the road in North Wales.

With regard to the mail-coach road between Shrewsbury and London, the Commissioners proceeded differently. In the first place, it was necessary to ascertain the precise line most advisable to be adopted; for which purpose I constructed a general map of the surface between London and Holyhead, delineating the present roads and principal towns, and by strait lines drawn upon this map, showing distinctly the relative position of the most important places. Induced by this and other information, the Commissioners preferred the Coventry road to that by Oxford, because it was ten miles shorter, and because the Liverpool mail-coach travelled a hundred miles upon the same line.

Between London and Shrewsbury were found seventeen separate turnpike-road trusts. With these the Commissioners did not materially interfere, either as to letting, collecting or applying the existing tolls; and each trust retained its own surveyor, and managed the usual repairs, so that the Commissioners could not procure funds, nor enter into any contract, until they had obtained the approbation of the local trustees for each proposed improvement. For removal of this obstruction, authority was given by Parliament to levy an additional toll, not exceeding one-half the previously existing toll, for defraying the expense of intended improvements. The performance of the contracts was encouraged and enforced in the same manner as in the case of the Welsh roads, and the portions first completed in England were immediately given over to the care of the local trustees; but it was discovered that these improved parts of an old road did not receive the attention which newly-made

roads require, until they are perfectly consolidated. This difficulty was obviated by another Act, authorizing the Parliamentary Commissioners to retain the management for two years after each improvement was completed; and by unremitting inspection, the road between London and Shrewsbury has (with few exceptions) been brought to an unprecedented degree of perfection. Annual Reports to Parliament, with particular details as to the management of the several road trusts, were found highly conducive to improvement.

In 1820, a deputation of the Commissioners, attended by their secretary and engineer, had conferences with ten different bodies of road trustees; in consequence of which, in my Report of May 1822, it is stated that contracts had been entered into for the following improvements:—1. At Hockliffe Hills,—2. At Brickhill Hills,—3. At Braunston Hill,—4. In Cuttle Mill Valley,—5. At Meriden Hill,—6. At Summer-house Hill,—7. In Cossford Brook Valley,—8. At Prior's Lee Hill,—9. In Ketley Valley:—

And since have been completed the following improvements;—10. At the Highgate Archway Road,—11. At Barnet and South Mims, by a variation of line,—12. At St. Alban's and Pond-Yards, by a variation,—13. Near Forster's Booth, sundry hills improved,—14. At the Forty-Mile and Sandhouse Hills,—15. At Fenny-Stratford and Old-Stratford,—16. At Stowe Hills, and to Weedon,—17. From the Seven Stars to Whitby Common,—and from Coventry to Allesley,—18. By the Wednesbury and Bilstone variations,—19. At the South approach of Wolverhampton,—20. By the Shiffnal variation,—21. By the Knowles Bank variation,—22. By the Llewellyn variation,—23. From Shrewsbury to Shelton,—24. From Gobowen to the entrance of North Wales, at Chirk.

The improvements upon the road between Shrewsbury and London, consisting of these and other detached portions, each having a distinct character, according to the nature of the hill to be cut down, or the valley to be raised, no general specification could be made applicable; but it is sufficient to state that the principle adopted in North Wales was preserved, and modified so as to suit the materials found in England. I shall therefore only introduce the specification for the improvement of Braunston Hill, as a specimen of the conditions required on a piece of road, which, after many years' experience, has since been found to answer every purpose, with very slight repairs. The road-making part applies equally to the variations at Stowe Hills, Meriden Hill, and to those on each side of Coventry. [*See* Appendix (O.)]

THE MENAI BRIDGE.

[*See* Plate 69.]

The most formidable obstacle in the whole of the line of communication between London and Dublin was the strait which separates the Island of Anglesea from the county of Carnarvon. This isle of MONA, the anciently-celebrated resort of the Druids, being wholly projected beyond the general line of coast into the Irish Channel (narrowed by it twenty miles), appears to have been selected for the last retreat of these mysterious bardic legislators. In common with other straits which separate any island from the continent, or from a larger island, this arm of the sea exhibits peculiarities in its tide, which, twice in every twelve hours, runs in different directions, and frequently with great velocity. The rise at ordinary spring-tides is about twenty-two feet, sometimes as much as thirty feet; and being in the vicinity of the Snowdon range of mountains, it is subject to violent gusts of wind, from

which liability, and from the ferry passage being frequently made in the night, this part of the journey was rendered a disagreeable object of anticipation, and was sometimes really dangerous.

This ferry, which is about a mile and a half south of the city of Bangor, was leased by Queen Elizabeth to John Williams, at the yearly rent of £.3. 6*s.* 8*d.*; and from him it descended to Lady Erskine. Being upon the principal road to Ireland, the intercourse had increased so as to produce an annual revenue of £.878.

To supersede this inconvenient ferry had long been considered an object of great importance, and had accordingly exercised the talents of many ingenious men. Schemes of various kinds had been proposed; bridges of stone and of timber,—a stone mound,—and even a tunnel under the bed of the rocky strait, had at different times been strongly recommended; but it was not until the date of the union with Ireland that the subject was noticed by Government. In that year (1801) the celebrated Mr. John Rennie was employed, and made two designs for bridges of cast-iron; one over the Swillies, another at the rock of Ynys-y-moch (Pig Island). But these plans were laid aside.

In the year 1810, while the North Wales road survey was in progress by public authority, I was directed to include the passage over the Menai strait, also over the Conway estuary; and designs for both these accompanied my Report of 1811, when circumstances occurred which led to the postponement of my two plans; and it was not until the year 1818, when the Holyhead road improvements had made considerable progress, that I was directed to re-survey the Menai strait, and to make a report as to the most advisable mode of passing it.

It so happened, that in the year 1814 I had been called upon to consider of the best mode of crossing the river Mersey at Runcorn, in Cheshire, with a view of shortening the London road to Liverpool; and under all the circumstances of the case, I recommended a bridge of wrought iron, upon the suspension principle; to prove which, I tried several hundred experiments upon malleable iron, in lengths from 30 to 900 feet, and from one-tenth of an inch to two inches diameter; and having thus obtained a knowledge of elementary facts, I constructed a model 50 feet in length, and ascertained its strength. [The Runcorn Bridge design is represented in Plate 83.] Although the project which gave occasion for these experiments was abandoned, they had authorized me to recommend a bridge upon similar principles over the Menai strait; and this, after much discussion, was adopted by Parliament.

In choosing between the two possible sites for this important edifice, I fixed on that of Ynys-y-moch, where the breadth of the estuary, at high-water, is 306 yards; at low-water, 160 yards. On the Anglesea side, the rocks rise to a height inconvenient for approach to the bridge; on the Carnarvon side, access might be selected at any convenient elevation. The main suspension-pier, on the Anglesea side, is placed upon the Ynys-y-moch rock, which rises above high-water mark. On the Carnarvon side, it was necessary to obtain a firm rock foundation, by sinking six feet beneath the level of low-water. The height of these main piers, from high-water to the roadway, is 100 feet; from thence to their apex is 53 feet. The road-platform is occupied by two parallel carriage-ways, each twelve feet in breadth, and a footpath of four feet between them, thus admitting of four distinct lines of suspension-chains, the distance between the points of suspension being 579 feet.

In the session of 1818, twenty thousand pounds was granted by Parliament in preparation for this work, and the intended road through Anglesea; and on the 8th of July carpenters commenced building workshops. The rocks in the immediate vicinity of the bridges were unfit for masonry, but on the Island of Anglesea, at the distance of twelve miles northward from the bridge, is an inexhaustible quantity of hard, grey limestone, of unlimited dimensions; and when the most convenient spot for quarries had been determined, barracks for workmen and shipping-piers were built; and during the remainder of the season, stones were quarried and prepared by the masons.

As the Carnarvon interest (headed by the persevering Mr. Asheton Smith) continued to raise fresh obstacles, by disputing the powers of the Commissioners, it was judged advisable to limit the operations to providing materials, and other preparations, until a new Act could be obtained, explanatory of the disputed powers. The Marquis of Anglesea was always friendly to the measure, and was satisfied that, by removing some of the Swilly rocks, the navigation of the strait would be improved.

In the year 1819, under a new Act of Parliament, the work proceeded with regularity. Vessels were provided for conveying stone and other materials; working drawings, with a specification, were prepared, and a contract was entered into with Messrs. Straphen and Hall, experienced builders, to perform the masonry at fixed prices; and on the 10th day of August, the first stone of this great work was laid by W. A. Provis, an intelligent young man, whom I had appointed to act as resident engineer, to superintend not only this, but all the works then in progress in North Wales. This first stone is in the middle of the lowest course of the sea-face of the Ynys-y-moch pier; and during this year, 200 workmen and five vessels were employed.

In the year 1820 several of the smaller piers were founded, also the large pier on the Carnarvon side. I have already observed, that this latter was founded at six feet under low-water level, and it was carried up with solid square masonry to the first offset before the open compartments were commenced; but in the Ynys-y-moch pier, those compartments were commenced immediately on the rock. I have elsewhere expressed my conviction, that one of the most important improvements which I have been able to introduce into masonry consists in the preference of cross-walls to rubble, in the structure of a pier, or any other edifice requiring strength. Every stone and joint in such walls is open to inspection in the progress of the work, and even afterwards, if necessary; but a solid filling of rubble conceals itself, and may be little better than a heap of rubbish confined by side-walls. The example of the pillars of St. Chad's church (Shrewsbury), when that edifice fell in the year 1788, was ever infixed in my memory. These pillars were built about the close of the reign of Richard II. (A. D. 1399); and I am bound from impartiality to add, that the piers of Westminster Bridge (no more than eighty years old) now exhibit an almost similar core of imperfect materials and workmanship.

On the 20th of March, the value of the ferry was determined by a jury to be £.26,954, being thirty years' purchase upon the annual rental. I had valued it at twenty years' purchase, not taking into account the compulsory nature of the sale.

Mr. Straphen being prevented by engagements from giving constant personal attendance, which was indispensable in a work of such magnitude and difficulty, he and Mr. Hall were relieved from their contract, and Mr. John Wilson undertook it at the same rates, and under the same conditions.

At the end of 1820, the state of operations on the Anglesea side was as follows:—The abutment was 14 feet above high-water; the small pier, next the abutment, 36 feet; the middle pier, up to the level of low-water; the next small pier was 43 feet above high-water mark; and the large pier upon Ynys-y-moch was 51 feet above the level of high-water. On the Carnarvon side, the large pier had reached high-water level; the small pier next to it, 45 feet above high-water; and the other small pier had attained the same height.

After sundry discussions, during the year 1820, respecting the iron-work, all the patterns and dimensions were finally arranged, and Mr. Hazledine, of Shrewsbury, entered into a contract to furnish the whole, at fixed prices. It was to be of the best Shropshire iron, drawn* at Upton forge, and finished and proved at his establishment near Shrewsbury; every operation to be performed under the inspection of a person (Mr. John Provis) who was appointed by me for that sole service. The iron-work, in this state, was sent, partly by land, direct to the Menai strait,—partly by canal to Chester, and from thence by sea to the bridge, the first cargo being delivered on the 3d of August 1820. The timber centering for the arches on the Carnarvon side was framed and fixed in its position; and during the year 1821, from three to four hundred men, and five to seven vessels, were employed.

At the end of the year 1821, the state of operations on the Anglesea side was thus:—

* Bar-iron is formed and variously fashioned by the process of being *drawn* repeatedly between cast-iron rollers grooved in various shapes, instead of incessant beating by tilted forge-hammers, for which the iron was repeatedly heated at much expense of time and labour; such indeed as retrospectively appears intolerable, and has heretofore prevented the extensive application of malleable iron, now a great instrument in modern improvements.

The abutment and wing-walls were 43 feet above high-water; the small pier next the abutment was 45 feet high, and a course of arch-stones set; the next small piers were 65 feet high, and a course of arch-stones also set. On the Carnarvonshire side of the strait, the masonry was in greater forwardness, all the arches and spandrils having been advanced up to the roadway, except part of the cornice; and preparations were making for the serious task of erecting the pyramid, over which the main-chains were to pass to their somewhat remote point of fixation, in the solid rock.

In January, February and March 1822, on the Anglesea side, all the piers had been carried to the springing-course, and the centerings fixed thereon; the main pier was carried higher, and the main-chainway tunnels in the rock completed, and drains made from them; iron plates were placed in the masonry, for attaching the vertical iron rods. so as to prevent undulation when the bridge came into use.

Regulations were made for proving the bars which constitute the main-chains. The cross section of these was 3¼ square inches in area, and, according to my experiments, they were capable of bearing a strain of 87¾ tons before fracture; but at one-half of this strain, they showed elongation; and to keep within that strain or tension, it was judged advisable to limit the proof to 35 tons, being about 11 tons to every square inch of cross section. A very accurate and powerful proving machine having been constructed, every piece of iron was submitted to the same proportional strain; and when in that state, it was frequently struck with a hammer; the length was adjusted by an unyielding iron gauge, and after being proved, every separate piece of iron was well cleansed, put into a stove, and when brought to a gentle heat, was immersed in a trough containing linseed oil. After remaining a short

time, it was again put into the stove, and, when dried, appeared covered with a varnish. When taken out of the stove the second time, each piece was finished with a coat of linseed-oil paint; and this dry, the iron bar was considered fit to be sent to the bridge. All this process formed the sole employment of Mr. John Provis, who superintended the preparation and proof of the iron-work.

In August, September and October, the arches on the Anglesea side of the bridge were completed, and the main-chain tunnels on the Carnarvon side commenced, the first barge-load of prepared iron-work was delivered, and Mr. Rhodes (a practical mechanic of first-rate ability) was engaged to undertake the junctures and fixture of the iron-work.

The number of workmen employed in the year 1822 was usually 260, and from five to eight vessels for carriage of materials.

At the end of the year 1822, the state of the work on the Anglesea side was thus:—

The abutment and its wing-walls completed; the large pier built to the level of the roadway; the intervening stone arches all finished, and their spandrils up to the cornice; the main-chain tunnels and drainage completed, as also the embanked approach to the bridge. On the Carnarvon side, all the masonry up to the roadway completed; the pyramid crowning the great eastern pier, above the level of the roadway, commenced, and the main-chain tunnels, with their drainage, about one-half finished; and 2,319 main-chain bars had been proved.

Mr. Rhodes arrived in the beginning of the year 1823, and the first iron-plate in the main-chain tunnel was fixed on the 31st of March.

the mode of fixing the main-chains in the rock being an important operation, and worthy inspection by every visitor of the bridge, who feels no dread at entering by a side-drain (on the Anglesea side) into a cavern in the rock, containing gigantic iron-work, and productive of feelings of superhuman agency. No precautions were spared to render every part perfectly true, and therefore secure; for as any variation in the length of the numerous bars would produce unequal bearings, each was subjected to a fresh adjustment by means of a steel model, upon which they were bored when cold, so that a cross-bolt passed through a certain number, in most cases through eight bars, so as to form four chains, thus accurately attached to each other.

The suspension pyramids were, in the year 1823, raised to the height of 30 feet above the level of the roadway, being perforated by carriage-ways of nine feet in width, to give access to the bridge. The masonry in these pyramids was secured by drilling holes through the courses, and by introducing iron bolts, fixed by Parker's cement; moreover iron ties are placed horizontally, at the springing of the arches over the carriage-ways. Powerful blocks, capstans and cranes were provided, also a pair of shears 74 feet in height; and as it was important to know with certainty what power would be required to raise the main suspending-chains to their proper curvature, an experiment was tried, with a real chain, over a small valley adjacent to the bridge, by which it was found that the absolute weight of one of the main-chains, between the points of suspension, was 23½ tons, requiring a strain of 39½ tons to raise it to its proper curvature; and all the necessary apparatus was prepared accordingly. The reader will keep in mind that the bridge depends on four times four main-chains, of similar and uniform tension or bearing.

In May and June 1824, the masonry of both pyramids was completed, and the cast-iron plates and saddles were fixed upon their tops; the saddles are so constructed, that the chains are moveable upon them, and the strain is conveyed to the extremities of each chain, which is fastened in the rock at the end of its tunnel; so that upon the pyramid-tops there is only a perpendicular pressure. Every part of these saddles is distinctly delineated, with references and explanations, in Plates 71, 72.

When the pyramids and the roadways over the masonry-arches were completed, temporary timber-framings were constructed between the pyramids and the points where the main-chains entered the tunnels. Upon these framings a set of four main-chains was laid, the ends being secured under the roadway, and the other ends carried to the top of the eastern and western pyramids respectively. On the Anglesea side, the chains so remained. On the Carnarvon side, the chains were not only carried along the timber-framing to the pyramid-top, but brought over and down its sea-face to high-water level; the portion of the chain which was to complete the line between the opposite pyramids was laid at length upon a timber float, moored on the Carnarvon side, westward of the great pier. Upon the Anglesea side, at some distance from the pyramid, capstans were placed, to which ropes were attached, of sufficient power for a strain of 50 tons. [Plate 73.]

Every necessary preparation having been made, about the middle of April 1825 I left London for Bangor; and having satisfied myself that every due precaution had been taken, it was resolved to raise the first chain on the 25th of that month. Accordingly, on that day, at half-past two o'clock in the afternoon, about an hour before high-water, the raft was cast off, and floated into position between the piers, where

being moored, one end of the chain, which lay upon it, was joined to that which hung down the face of the Carnarvon pier; the other end was attached to ropes connected with the Anglesea-side capstans, and the said ropes passed, by means of blocks, over the top of the pyramid of the Anglesea pier. Then the workmen who manned the capstans moved at a steady trot, and, in one hour and thirty-five minutes after they commenced hoisting, the chain was raised to its proper curvature, and fastened to the portion of chain previously placed at the top of the Anglesea pyramid. I then ascended, and satisfied myself that by this juncture had been formed a continuous and safe chain from the Carnarvon fastening in the rock to that in Anglesea. Having announced this fact, a loud and general shout of exultation arose from the workmen and the numerous spectators who had assembled to witness this novel operation. On Saturday, the 9th of June 1825, the last of the sixteen chains was raised to its place in this manner, and the temporary framing removed. In each chain are four adjusting links, by means of which it can be brought to the proper curvature; and, by experiments, it has been ascertained, that any part of any chain may be taken out and replaced, without endangering the stability of the bridge.

In August the construction of the road-platform was commenced, and in September the trussed bearing-bars were all suspended. The platform of the roadway consists of two thicknesses of fir-plank, both laid longitudinally upon the trussed bearers. The lower planking is three inches, the upper two inches in thickness; between them there is a complete coating of Borrodail's patent felt, saturated with boiled tar. The two layers of planking are spiked together, and both attached to the two trussed bearing-bars by bolts which pass between them. In each carriage-way there is a third layer of planking across the former, also laid on patent felt, which last planking, when worn by carriage-

wheels, may be replaced without affecting the essentials of the bridge. Along each side of the carriage-ways are oak-guards (twelve inches by eight) placed seven feet and a half apart.

In the latter end of the year 1825, the side-railings were added, and the toll-houses and gates completed, also the roads of approach; and Henry Fisher, who had assisted in putting up the iron-work, as the foreman of Mr. Rhodes, was appointed bridge-keeper and principal toll-collector; and a carpenter, who had been employed during all the bridge operations, became the other collector and assistant, their practical knowledge being important in watching the effects of heat and cold and tempests on the new structure.

Upon my report of the state of the works, the Commissioners determined that the passage over the bridge should be opened on the 30th of January 1826. The weather, about that time, proved very stormy; and previously to the opening day, Sir Henry Parnell and myself examined the entire structure, and found all necessary arrangements made. On Monday morning, at half-past one o'clock, the London mail-coach, occupied by W. A. Provis, W. Hazledine, the two junior Wilsons, Thomas Rhodes and the mail-coach superintendent, was the first that passed across the estuary, at the level of 100 feet above that tideway which heretofore had presented a decisive obstruction to travellers. The Chester mail passed at half-past three o'clock, and Sir Henry Parnell, with myself, drove repeatedly over; about nine o'clock, and during the whole of the day, was an uninterrupted succession of passing carriages, horsemen and pedestrians, who had assembled to witness and enjoy the novelty; and in the evening all the workmen were regaled with a joyous festival.

Thus was successfully accomplished a complicated and useful bridge of unexampled dimensions, which has now, for the last eight years, converted what was formerly a disagreeable and sometimes dangerous part of the journey to and from Ireland, into an object of national curiosity and delight.

The engraved Plates already referred to, and inserted in the Atlas annexed to this volume, will afford a distinct idea of the general appearance, as well as of the several parts; and Plates 74, 75, show various machinery and tools used in the construction of the Menai Bridge; but for a full and detailed account of the progress of the works, and for a minute narrative of every operation, I must refer to the standard description published by the resident engineer, Mr. W. A. Provis, who faithfully superintended the performance of the whole, from its commencement to completion. I shall therefore only further state, in summary, that in the breadth of the bridge there are 16 chains; each chain is composed of 935 bars; and its total length is 1,710 feet, or nearly one-third of a mile.

The number of suspension-rods affixed to each series of four chains each, is 199; the total number, 796. The total number of trussed bearing-bars is 444, and the total weight of iron-work is 4,373,282 lbs., or above 2,186 tons. The best view of the suspended portion of the iron is from beneath, on the Anglesea side of the Menai estuary. The iron-work is protected externally from the effect of the weather by paint, a coat of which weighs about two tons and a half.

CONWAY BRIDGE.

[*See* Plate 78.]

Edward I. built Harlech, Carnarvon and Conway Castles. He had, no doubt, improved his European knowledge of such structures during his warlike crusades to the Holy Land; and the conquest of Wales afforded an opportunity for a display of the skill of his military architects, who had also studied Asiatic fortification.

Conway Castle was, and, with some renovation, would now become once more, a spacious and magnificent fortress; and the unbroken wall, which still encompasses the adjoining town, exhibits signal excellence of workmanship. The castle is placed on a mass of rock, at the mouth of the river Conway, and, by projecting into the tideway, was difficult of approach to an enemy, but well adapted for receiving succours from England, in case of need. These motives have ceased, and, instead thereof, advantage is now taken of the projecting rock for the improvement of civilized intercourse.

The communication between London and Dublin was, for many years, by way of Chester, and the sea-passage commenced near the mouth of the Dee, at Park-gate; but, from its shortening the sea-passage, Holyhead had in fact superseded that station. The road from Chester encountered two ferries, of which the most inconvenient and dangerous was that at Conway. Although, from this cause, it had been found advisable to send the London mail by Shrewsbury, and direct through North Wales, thus avoiding Conway ferry, yet as the Irish letters from Manchester and the north-west of England continued to be sent by way of Chester to Holyhead, the inconvenience created by this ferry

was felt to be so serious, that a plan for a bridge was included in my Survey of 1811.

It had been suggested, that by leaving the shore at the village of Aber, and passing to the south-east of Pen-man-Mawr, the valley of the river Conway might be crossed with advantage about two miles above the town of that name, where its channel becomes contracted; but, upon examination, this was judged unadvisable.

On considering the shape of the rugged mountains, which, westward of Conway, form bold sea-promontories, I foresaw that the mail-coach road must eventually be constructed along their base, as nearly as practicable to high-water mark; and, under this impression, the propriety of crossing the estuary about a mile below the town became a debateable question. To determine the propriety of this, I caused two surveys to be made, but found that the proposed site would be greatly exposed to storms from the north-west, and that the foundations were unfavourable; so that, on the whole, the passage opposite the old castle possessed superior advantage, as compared to any other. From the western shore to a small rocky island, at the distance of about a hundred yards, was a well-sheltered situation, with rock quite across the channel, so that increased velocity only could take place from turning the whole flux and reflux of the tidal waters through that space, there being no risk of the rock being washed away. To accomplish this object, it was necessary to make the eastern approach by an embankment between the before-mentioned island and the eastern shore. This was done, and has already been described (p. 213).

The bridge is upon the same principle as that already described over the Menai strait. The distance between the points of suspension is

327 feet; the depression or versed sine of curvature of the main-chains is 22½ feet; the number of chains is 8, having each 5 bars, 3¼ inches by 1 inch, making together a total of 130 square inches of transverse section. The roadway is 17½ feet in breadth, and is 15 feet above high-water. It consists of one carriage-way, without any separate foot-path; and the intercourse not being so great as at the Menai bridge, no interruption is experienced. The several parts of the chains, and their fixtures, are similar to those in the Menai bridge, but the main-chains were put up by a different process. The float already referred to was towed round to Conway, but the current between the island and the castle-rock was so strong that it could not be moored with sufficient precision. This mode was therefore abandoned, and the strong rope-cables used for hoisting at the Menai strait were stretched across, between the tops of the supporting pyramids (or rather towers), six on each side of the bridge, and thus were made to bear temporary platforms of planks; upon these the chain was laid, and united with that portion of it which had been brought up from the fixation in the rock-galleries to the top of the pyramidal towers. The platforms were then removed, the rope-cables were slackened, and the chain lowered to a proper curvature. The side-railing was afterwards affixed, the iron-work painted, the road-platform constructed and coated, all as at the Menai bridge. The Conway bridge has afforded a commodious thoroughfare, and, on my survey of it in 1834, was in a very perfect state. Its plan, elevation, the adjacent rock and its castle, are delineated in Plate 78.

The road seems to aim at a direct entrance into the old castle, but in fact is carried around its basement of rock, and passes through a gateway in the town-wall. Upon the rocky island there is exactly space enough to admit of chain-tunnels being excavated, and for

building a toll-house. In the elevation of the supporting towers, of the toll-house, gateway, breast-walls and parapets, attention has been paid to the castellated style; so that the bridge, which is right opposite to the water-entrance of the castle, has the appearance of a huge draw-bridge, with an embanked approach or causeway. Including the castle, the town, the wooded hills on each side the estuary, and the rugged mountains in the back-ground, with the Great Orms-Head on one hand, and the fine valley of Llanrwst on the other, the whole view embraces a landscape seldom equalled in the variety of its command of the beauties of natural scenery, and of the works of man.

Mr. John Wilson undertook the masonry of this bridge; William Hazledine made the iron-work; Thomas Rhodes fitted and fixed it; and W. A. Provis superintended the whole of the operations; all these having brought with them the experience obtained at the Menai bridge.

It has already been stated, that on Lord Oriel's retiring from public life, Sir Henry Parnell, Member of Parliament for Queen's County in Ireland, and since for the town of Dundee in Scotland, was not only the principal instrument in carrying the Holyhead Road Bills through Parliament, but has ever since continued to be the most efficient of the Commissioners. Fully impressed with the importance of rendering the communication between London and Dublin perfect, he has, during the last twenty years, applied himself to that object, for effecting which both talents and management have been required, as well as perseverance:—

(1.) He had to convince Government of the advantages to be derived from the scheme, and induce them to furnish the means of defraying the expense;—(2.) To procure the consent of all the numerous, and, in

some instances, turbulent bodies of local trustees, upon an extensive line of road;—and (3.) To arrange the sea-communication between Holyhead and Dublin, for which purpose the harbour of Holyhead was improved, in a manner which has rendered it serviceable as a harbour of refuge, far beyond its immediate purpose for the protection of the packets [*see* Plate 79]; and a harbour has also been made at Howth, northward of the bay of Dublin. All this he has effectually accomplished; and by extending his services beyond the usual duties of a Parliamentary Commissioner, and therein devoting much of his time to the personal inspection of practical operations, he has acquired so perfect a knowledge of road-making in all its branches, as has enabled him to produce the most valuable treatise which has appeared in England on the history, principles and practice of that species of national improvement.

EXCHEQUER BILL LOAN COMMISSION.

After a war of unexampled extent during more than twenty years, in part of which England stood unaided by a single ally,—the peace of 1815 was welcomed as the harbinger of plenty and domestic happiness; but this natural expectation had in truth become quite unfounded from the time when wars had been decided by the wealth and national credit of Great Britain, quite as much as by conduct and courage in the field of battle. The expense incurred by assistance afforded to our allies and for our own hostile purposes, had amounted to a hundred millions annually during the last years of the war; and on the moderate supposition that one-third of this enormous diversion of capital was expended in payment of native soldiers and sailors, and of the more numerous workmen employed in the manufactures and other

occupations created by war, we behold at once a million of human beings thrown out of their usual means of subsistence, and pressing for admission into all other classes of society, so that suddenly the supply of labour outstripped the demand, and wages declined accordingly. Capital, it is true, which had supplied and sustained the war expenditure, no longer found investment in national loans, and had to seek for other application; but this was not immediately attainable, and society had to sustain a derangement some years in duration, before employers and the employed had established a mutual connection in the arts of peace and of improving civilization.

In the year 1817 Lord Bexley was Chancellor of the Exchequer, and had cause to triumph over the sarcasms of his political opponents, refuted as they were by notorious fact, when the Bank of England note rose to its full value throughout Europe within a year after the proclamation of peace. But this good man and real patriot rather occupied himself in finding remedy for the revulsion by which all the industrious classes of society were sorely distressed; and by a judicious extension of the principle by which local visitations and mercantile embarrassment had sometimes been relieved, he effected his object by a grant of Exchequer Bills, to be expended in public works, personal security being given by the borrowers.

An Act was accordingly carried through Parliament with the following Preamble: 'Whereas great advantages may arise, under the 'present circumstances, in affording employment for the labouring 'classes of the community, by the advance of Exchequer Bills and 'money out of the Consolidated Fund, to an amount in the whole 'not exceeding the sum of One million seven hundred and fifty 'thousand Pounds, to be lent by commissioners in Great Britain and

'Ireland respectively, under certain regulations and restrictions, for 'carrying on works of a public nature, commenced, or which may 'hereafter be commenced, under the authority of Parliament.'

The Commissioners under this Act appointed me to exercise my judgment on all works requiring the opinion of a civil engineer; and in that capacity I examined and reported on the plans, specifications and estimates of sundry works, in aid of which applications were made to the Commissioners.

In the year 1817 the Regent's Canal, which proceeds from the Grand Junction Canal at Paddington, and passes along the northern boundary of the Regent's Park, through Islington, to the river Thames at Limehouse, had been partly executed, but being then deficient in funds, applied to the Exchequer Bill Commissioners for a loan.

The metropolis had increased so as to occupy all the space between the river Thames and the base of the Hampstead hill, and the supply of timber, coals, and other bulky articles, had become inconvenient and expensive to the inhabitants. The principal streets of London, also, running east and west, were liable to obstruction from the numerous heavy carriages of various descriptions crossing them in their passage from the river to the northern parts of this great city. A navigable canal, therefore, connecting itself with the river at one extremity, and the Grand Junction Canal at the other, promised much public accommodation.

The Commissioners having weighed all these circumstances, accommodated the Canal Company with successive loans to the amount of £.250,000; but this canal, however useful as a connection between the

Thames at Limehouse, and the Grand Junction Canal, has not sensibly superseded land-carriage in the streets of the metropolis, the delivery of all commodities rendering necessary their being placed on wheel-carriages, and short distances adding little to that expense.

In the same year (1817) the following applications were made for assistance:—

2. For a cast-iron bridge across the Thames, from Southwark to Queen-street, Cheapside - - - - £.78,000.
3. For a short canal between the Thames and Isis Navigation, near Lechlade, and the Wilts and Berks Canal [*Not granted.*]
4. For an enlargement of Folkestone Harbour, on the coast of Kent - - - - - - - - £.10,000.
5. For completing the Thames and Medway Canal at Gravesend. [*Not granted.*]

All these I examined, and reported upon to the Commissioners.

In the year 1818:—

6. The Gloucester and Berkeley Canal Company applied for a loan to enable them to finish that work, which had been commenced about 30 years previously. This was granted, and the canal was finished under my directions [as described in the following pages, 240—243] - - - £.160,000.
7. In the year 1821, the Portsmouth and Arundel Canal Company obtained a loan* to complete that work, in order to open a

* The application of this loan, for repayment of which the Earl of Egremont gave ample security, was not a little remarkable, and one of the effects resulting from it may here be narrated, as a caution useful not only to civil engineers, but to all the inhabitants of a neighbourhood where any canal approaches the sea so nearly as to be filled with salt water.

An inland navigation had been opened between Arundel (Sussex) and Guildford (Surrey), from which last place, by means of the river Wey (one of the earliest rendered

communication between the town of Portsmouth and the navigable river Avon - - - - - £.40,000.

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navigable by art), water-carriage was obtained to the Thames at Weybridge and with London itself. The proprietors of the Arundel Canal having been thus far successful, thought that, by extending their canal westward to Portsmouth, great advantage might accrue, especially in time of war, when naval and other stores are sometimes required for urgent occasions which cannot await uncertain arrival by the usual shipment in the Thames; on which consideration the Admiralty countenanced this enterprise.

The connected harbours of Chichester and Langston cover one-half of the distance between Arundel and Portsmouth, so that, by means of an actual canal across the fertile level ground between Arundel and Chichester Harbour, a sheltered salt-water navigation was open quite to Portsea Island, on the west side of which is situate the town and harbour of Portsmouth; to arrive at which, a canal across the Island of Portsea, three miles in length, was necessary. Nor were the projectors satisfied with less than a ship-canal, thereby increasing its depth and surface, the latter to a chain (twenty-two yards) in breadth, and doubling evaporation to the amount of twenty-four acres in the three miles. This ambitious enterprise could not be successful unless by a steam-engine pump for the supply of salt-water from Langston Harbour, and in fact no sea-going vessel ever made the passage except a collier, by which the ceremony of opening the canal was accomplished (1823).

This might be deemed a failure, to which all human enterprises, however well concerted, are liable; but a positive evil supervened, for explanation of which, it is necessary to premise, that the islands, as well as the Peninsula of Selsey, which here form the outline of coast, are but ancient accretions of gravel now covered with fertile soil; and their surface, from the nature of their origin, not less high than the highest spring-tides urged by a westerly storm. On this level, perhaps a water-tight boat-canal might have been established, but the depth of a ship-canal penetrated the open gravel, and the soakage was such as to surpass the countervailing power of supply. But before the hopeless effort ceased, an alarming nuisance occurred, by the contamination of all the well-water in a populous suburb of Portsmouth; even the pipe-water for supply of the town was vitiated, and the demands against the Canal Company for compensation could not be satisfied. A supply of pipe-water was, after some interruption, obtained from a deeper source, but the wells have not yet recovered their former purity. The Canal Company sought to lay the blame on their contractors, who, they contended, ought to have made the canal water-tight. To do so, if practicable, the contractors replied, would have doubled the expense, and that they were not answerable for the unforeseen effect of their operations in conformity to contract.

The dispute was referred to a barrister, and Mr. Telford was solicited to inspect and report upon facts; but in the result, no compensation was obtained by the sufferers, and the Canal Company fell into abeyance.

Some years afterwards (in 1828) the Canal Company made another effort, and obtained an Act of Parliament, under which they attempted access for canal boats to Portsmouth Harbour by enlargement of the small natural creek which separates the

8. In the year 1822, the ferry-trustees of the passage across the estuary of the Tay, at Dundee in Scotland, obtained a loan, and constructed landing-piers according to my plan, as already described [Page 147] - - - - £.25,000.
9. In the year 1823, a loan was granted to the Bude Navigation Company, in aid of a canal, or rather of several canal levels, connected by inclined planes, and penetrating the county of Devon from the north-west coast - - - £.20,000.
10. In the same year, a bridge in the city of Oxford, over the river Isis, was rebuilt, in place of an old bridge on which was the site of the celebrated Friar Bacon's study - £.6,000.
11. Porthlevin Harbour, in Cornwall, was also completed, £.22,500.
12. In the year 1824, Sir George Ducket made a navigable communication between the Regent's Canal and the river Lea, by means of a loan - - - - - - - £.20,000.
13. In the year 1825, the corporation of the town of Kingston-upon-Thames obtained aid towards building a stone bridge, in place of a decayed wooden bridge; and this has been completed in a proper manner, forming a more commodious communication across the Thames, within twelve miles of the metropolis - - - - - - - £.40,000.

Isle of Portsea from the main land of Hampshire; but neither has this expedient been prosperous.

Yet it may be useful in this place to state the facility which exists by closing the mouth of Langston Harbour (no difficult operation), and, by a greater enlargement of this creek, to use that harbour as a back-water, and render Portsmouth Harbour available for the berthage of an increased number of ships at pleasure, and by the same back-water to deepen the entrance to sea-ward, which last is very desirable, the soundings being so scant, that three-deckers mostly receive their guns after reaching the Spithead anchorage. It is only necessary to add, that the substratum of the creek being very solid chalk, the dimensions of an increased channel would always be unalterable unless purposely increased after experience of the quantity of back-water requisite or desirable for the above improvements.

In 1826 and the following years, the after-mentioned works have obtained aid from the Exchequer Bill Commissioners:—

14. A ship-canal between the city of Exeter and the sea, at the mouth of the river Exe. [*Not granted.*]
15. The harbour of New Shoreham, in Sussex (in fact, the harbour of the flourishing town of Brighthelmstone), rendered accessible and safe - - - - - - - £.15,000.
16. A bridge over the Teignmouth river (Devonshire) - £.8,000.
17. The Bridgewater and Taunton Canal.
18. Sundry locks and weirs upon the Thames and Isis Navigation - - - - - - - - - £.13,000.
19. Towards completing the Liverpool and Manchester Railway - - - - - - - - £.100,000.
20. Towards completing the Courtown Harbour in Ireland, £.6,000.

At the same time I was employed in inspecting and re-surveying the proposed Ulster Canal in Ireland, and aid was afforded to the amount of - - - - - - - - - - £.120,000.

GLOUCESTER AND BERKELEY CANAL.

This canal having been completed, as already mentioned, under my direction, I consider it to be my duty to describe it as a work of no small importance. The city of Gloucester being placed on the river Severn, at the head of the deep inlet usually called the Bristol Channel, it is nearer to the middle districts of the kingdom than any of the other great ports. In passing from Birmingham by water-conveyance, the distances are,

To London by Warwick, 154 miles, or, by Coventry, 180; to Liverpool, 116; to Hull, 152; and to Gloucester, 60 miles.

The intercourse between Gloucester and the populous midland counties is by means of the navigable river Severn, and the several canals connected with it; but from Gloucester downward to King-Road, by reason of the circuitous course of the river, and the rapidity of the tides, the navigation by undecked barges is difficult and dangerous, and even by small coasters; and these obstacles led to the project of making a ship-canal from the city of Gloucester to the open estuary at Berkeley-Pill.

The first Act of Parliament for this purpose was obtained in the year 1793, and practical operations were commenced by a joint-stock company, from a design and under the direction of Robert Mylne, the architect of Blackfriars Bridge, and engineer to the New River Company. At Gloucester was made a basin and its entrance-lock, connected with a branch of the river, and from thence a canal of about eight miles on low ground southward; but, as in many other projects of that date, the supply of money failed, and the work remained in an imperfect state until the year 1818, when it was resumed by means of aid from the Exchequer Bill Commissioners.

Previously to the work being recommenced, it was ascertained that the proposed entrance at Berkeley-Pill would be much exposed to the prevailing south-west winds, and that a more advisable entrance might be established under a projecting headland called "Sharpness-point," where, constrained by a rocky shore on each side, the river-channel was the only passage for the flux and reflux of the tide, which thus secured deep water, free from sand and the mud-banks elsewhere collected on flat shores of the Severn estuary.

Here, under the protecting headland (Sharpness-Point), an entrance-basin and extensive masonry-piers were constructed, and by a large

tide-lock the canal was at once raised to the same level as in Gloucester basin. Adjacent to Sharpness-Point, from the canal being carried about a mile along the face of a very steep bank of rock-marle, its whole breadth, and all the outer bank, required to be formed and secured by a sea-wall. At the entrance, besides the sea-lock for vessels of 300 tons, one of smaller dimensions, adapted to barges of 70 or 80 tons burthen, was also built.

At this entrance it is high-water (at spring-tides) at 7 o'clock, and the depth from 26 to 28 feet upon the lock-sills; at neap-tides, from 14 to 16 feet; the length of the canal is more than 16 miles, and its depth 18 feet. With regard to a supply of water, the river Frome (after descending from the Cotswold hills, near the north-west end of the Sapperton tunnel and town of Stroud, through the populous clothing country, to the Severn at Framilode) crosses in its course the Gloucester and Berkeley Canal, and thus affords an abundant supply of water. By this same junction of navigations, a connection is formed with the Thames and Severn Canal, and thereby with the metropolis itself.

From 1827 to the end of 1831, the custom-house revenue of the Gloucester Canal has increased from £. 2,836 to £. 10,879 and £. 12,000 per annum; and there is reason to expect, that in course of time the port of Gloucester and its canal will, from its local advantages, continue to increase in importance. The basin at Gloucester is already surrounded with commodious warehouses, timber-yards and coal-wharfs.*

* The increase of commerce at the Port of Gloucester, and its importance as compared to other Ports, may safely be measured by the amount of Custom-house duties collected since the year 1826:—In 1827, £. 28,550; in 1830, £. 90,281; in 1833, £. 106,751; in 1836, £. 166,187; but in the year 1837 (from the prevailing depression in mercantile credit) the Customs duties fell to £. 132,878.

But to promote its welfare to any great extent, a navigable canal should be carried from Gloucester upwards, by Tewkesbury, to the Birmingham and Worcester Canal, with a branch to Cheltenham; by which means all commodities from the interior would be passed in canal-boats to the ship's side at Gloucester, without entering the river Severn.

On my inspection in February 1832, I found 58 vessels in the Gloucester basin, 33 of which were sea-going ships.

ROAD SURVEYS.

SOUTH-WALES.

In addition to the works hitherto described, and which have been executed, I have now to mention Surveys made either immediately by the order of Government, or by direction of the General Post Office, in consequence of instructions from the Treasury.

The advantages arising from the improvements on the road between London and Dublin, by way of Holyhead, attracted the attention of the inhabitants of South Wales, and also those of the southern parts of Ireland, especially Waterford and Cork, and led to applications that Government should direct a general survey to be made through South Wales, in order to determine the proper direction of mail-coach roads between the south-west of England and the most commodious steam-packet station for the south of Ireland. Under these instructions, I made the extensive Surveys now to be described.

At present the mail-coaches pass through South Wales by two separate lines from London to Carmarthen, where they unite and proceed to Milford Haven. The inland or more northerly line passes through Oxford, Gloucester, Monmouth and Brecon, to Carmarthen; the other, or shore-line, passes through Bath, Bristol, Newport, Cardiff and Swansea, to Carmarthen also; and after this junction, the road passes through Haverford-West to Milford.

Nearly the whole of the rivers and streams in this part of the kingdom descend to the southward, and those in South Wales find their course in deep valleys, separated by mountain-ridges; so that the mail-coach road, by endeavouring to pass in a westerly direction, undergoes many awkward windings in order to avoid steep hills, as well as for the accommodation of post-office towns; as will become evident, upon considering that, measuring from a direct line drawn between London and Milford, on the inland or northern line of road, the city of Oxford is situated 12 miles to the northward;—Gloucester, 18 miles;—Ross, 21 miles;—Monmouth, 12 miles;—Brecon, 20 miles;—Llandovery, 22 miles;—and Carmarthen, 8 miles:—and that, on the southern or shore road, the towns are distant from the same direct line, as follows:—Bath, 16 miles southward;—Bristol, 12 miles;—New Passage, 3 miles;—Newport (Monmouthshire), 4 miles;—Cardiff, 10 miles;—Cowbridge, 13 miles;—Swansea, 8 miles: all southward;—but Carmarthen is 8 miles north of the same line. In this last instance, the road passes from 8 miles on the south side of the direct line, to 8 miles on the north side, in 28 miles; and it being necessary to preserve the intercourse through the principal towns, no very material change of general direction was found practicable. Under these circumstances, I perceived that, in the survey which was confided to me, the following objects were chiefly to be attended to:—1. To render all acclivities suitable to the

present rate of travelling in wheel-carriages;—2. To introduce a more perfect construction and shape of the road;—3. To establish a safe and commodious packet-station;—4. To discover means of enabling the mail-coach by the shore road to arrive at the packet-station about two hours earlier;—and after perambulating the entire district, and causing the necessary surveys to be made, I delivered to the General Post Office maps, sections and reports, showing in what manner these several objects might best be accomplished.

LONDON TO LIVERPOOL.

The rapidity and regularity with which the passage was made across the Irish Channel at Holyhead, led to the formation of steam-boat establishments for passing between Dublin and Liverpool; and although the distance by sea is twice as great as that by Holyhead, yet the passage being made with regularity in about fourteen hours, it was found greatly to facilitate the intercourse between Dublin, Liverpool Manchester and Belfast, and eventually with London itself

These circumstances induced the inhabitants of Liverpool to turn their attention to the imperfect state of their mail-coach road to London; and they made application to Government for surveys on the same principle as had been carried into effect on the Holyhead road; the result of which was, that I received instructions from the General Post Office to examine and report upon this important line of communication.

The Liverpool mail-coach travels by St. Alban's, Towcester, Dunchurch and Coventry, to Stonebridge in Warwickshire, on the same road as the Holyhead mail. Here it turns to the right hand, and

passes through Coleshill to Lichfield, and from thence up the valley of the Trent, by Stone, to Newcastle-under-Lyme; then through Cheshire, by Congleton and Knutsford, to Warrington; and from that town, by Prescot, to Liverpool.

As far as Dunchurch, in Northamptonshire, the road is sufficiently direct for the accommodation of both mails; but Coventry and Coleshill are too far to the west. A strait line between London and Liverpool passes through Tamworth, or rather Fazeley and Lichfield; and after surveys in sundry directions, I found that, on the whole, the line from Dunchurch, by Fazeley, to Lichfield, was most advisable, it being sufficiently level, and saving upwards of four miles in distance; but I also showed, that very considerable improvements might be made on the Coleshill line. Upon both lines road-making materials were abundant, and of excellent quality. Hartshill, near Nuneaton, consists of green-stone or quartz, which is quarried and broken to a proper size near the banks of the Grand Trunk Canal; and when employed as a coating upon the middle or workable part of any roads, it becomes so hard, smooth and durable, that it would be advantageous to use it on the roads towards London, as far as the point where Guernsey stone would come in competition with it.

From Lichfield, by Stone, to Newcastle, the general direction of the Trent valley is (notwithstanding local deviations) not unsuitable; but between Newcastle and Liverpool, the mail-coach route (as has been mentioned) was very circuitous. If, indeed, the estuary of the Mersey could be crossed at Runcorn, and a strait road made from thence to Liverpool in one direction, and to Newcastle in the other, there would be a saving of distance, when compared with the route by Congleton, Knutsford and Warrington, of about eleven miles; but by my surveys, I found

that, avoiding Congleton and Knutsford, adopting the most direct line to Warrington, passing on the west side of the town, and improving the Prescot line, the comparative saving by Runcorn would be reduced to about four miles; while the river Mersey is a well-frequented navigation, and the expense of making such a bridge over it as not to create material inconvenience, I estimated at upwards of £.100,000, a sum not to be justified for saving a distance of four miles; so that I concluded the Liverpool mail-coach road must always pass by Warrington; and in the years 1826, 1828 and 1829, I furnished the General Post Office with maps, sections and reports, shewing the comparative merits of the sundry lines which had been suggested and surveyed.

After all the before-mentioned surveys had been made at the public expense, and the road-trustees of the Coleshill and Fazeley lines furnished with copies of them, and with every necessary information to enable them to obtain authority from Parliament to make the improvements, nothing effectual has hitherto (in 1834) been accomplished.

In turnpike-roads of this extent, under the management of numerous trusts, no combined effort is made, or uniform plan adopted, not only because the different trusts are unwilling to co-operate, but because the individuals who compose such trusts seldom act with unanimity; and it was only under the controlling influence of Parliamentary Commissioners that the Holyhead road and the roads in Scotland were carried on with uniform success, and brought to a perfect state. In fact, it is useless to form good plans, unless they are executed under constant and strict inspection; for unless roads are effectually constructed at first, they ever afterwards continue to become imperfect, and cannot be maintained at a reasonable expense.

EDINBURGH TO LONDON.

Northern Division.

The advantages derived from the Highland roads made in the four northern counties of Scotland, the improvements made in the Glasgow and Carlisle road, and in Lanarkshire, and above all, in the road between London and Dublin by Holyhead, diffused the spirit of road-improvement throughout the whole kingdom; and the perfected roads having justified a correspondent improvement of wheel-carriages, a rapid intercourse was established, first in mail-coaches, and eventually in carriages of all kinds, until the usual rate of travelling had increased from five or six miles to nine or ten miles an hour. The appetite for rapid communication of political and commercial intelligence was found to increase with the means of obtaining it, and the possibility of delivering letters and newspapers a few hours earlier has stimulated unusual exertions, especially in the Post Office department.

In Edinburgh, where a central Post Office exists, and where intelligent individuals associate, the subject of improved intercourse was discussed with characteristic ardour, which produced urgent memorials for surveys on the principle of the before-mentioned roads; that is, by selecting lines most advantageous for general intercourse between Edinburgh and London, regardless of local interests. Hereupon Government considered the subject as of sufficient importance to authorize the General Post Office to ascertain the best lines; and it was under such authority that the several surveys were made which I purpose now briefly to describe.

THE HEXHAM LINE.

Leaving the Carlisle road at Catterick Bridge, in Yorkshire, and proceeding by West-Auckland, Witton-le-Wear and Walsingham, to

Hexham, and thence up Reed-Water to a summit-pass in the Cheviot range at Carter-Fell, and thence to descend to the town of Jedburgh in Roxburghshire, produces the following distances, reckoning southward:—

	Miles.	Yards.
From Edinburgh to Jedburgh - - - -	46	–
Jedburgh to Huntford Bridge - - - -	9	–
Huntford Bridge to Catterick Bridge - - -	90	960
	145	960
Catterick Bridge to London - - - - -	230	1,540
Edinburgh to London by Hexham - - - -	376	740

The two summits on this surveyed line are the pass at Carter-Fell, which is 1,416 feet above the sea, and that above Catterick Bridge, which is 1,106 feet above the sea.

Between West-Auckland and Jedburgh, the line passes through a thinly-peopled district; and between Walsingham and Hexham, the route is very hilly, as being intersected by deep valleys; and between Hexham and Jedburgh, the Cheviot-range is crossed on Carter-Fell; so that, although Hexham and Jedburgh appear in a strait direction on a map, yet in execution, this line would only admit of a crooked and imperfect road, with a very high summit, and must therefore be rejected.

ALDSTONE-MOOR LINE.

Another line was then surveyed, which leaves the Carlisle road at Greta-Bridge, and proceeds up the Tees valley to its summit, at Aldstone Moor (2,072 feet above the sea); then, after passing through the town of Aldstone, and down the South-Tyne valley, it crosses the Irthing five miles east of Brampton, passes on to Bewcastle, and terminates at the town of Castleton, in the county of Roxburgh. The distances on this line are as follows:—

	Miles.	Yards.
From Edinburgh to Hawick - - - -	47	1,100
Hawick to Castleton - - - - - - -	20	-
Castleton by Greta Bridge to Catterick Bridge -	84	1,364
	152	704
Catterick Bridge to London - - - - - -	230	1,540
Edinburgh to London by Aldstone - - -	383	484

The summits are as follows:—Castleton, above the sea, 504 feet; Aldstone Moor summit, 2,072 feet; near Catterick Bridge, 310 feet.

The whole of this tract is mountainous, with a scanty population. The summit is 656 feet higher than that at Carter-Fell, and the distance seven miles more than on the rejected Hexham line; so that no inducement exists for establishing a mail-coach road in this direction, although it would be useful for local intercourse.

WOOLER AND COLDSTREAM LINE.

The lines I have hitherto described being, in many respects, objectionable, and the Cheviot mountains extending eastward to Wooler, in Northumberland, it was found advisable to carry a survey from Morpeth, by Coldstream, avoiding the Cheviot-range, and connecting at Morpeth with the present north road, through Newcastle-on-Tyne.

Considering that the first eleven miles from Edinburgh, southward, might be left to the inhabitants of that rich and populous vicinity, I commenced the survey at Path-head, and from thence proceeding southward, ascended the summit of Soutra Hill, which is 1,184 feet above Berwick Quay; from thence I descended the Leader valley, to opposite the town of Lauder; then passing eastward, by Whitburn, and over an extensive level moor, to Greenlaw, I afterwards descended by the east side of Hirsel Park to Coldstream Bridge, upon the river

Tweed. Thus far (with the exception of Soutra summit), by judicious management, a sufficiently direct and commodious mail-coach road may be obtained. Upon the map and section I marked the necessary variations, as well as the present road.

From Coldstream to Wooler the road is on comparatively level ground, nearly in a strait line, and, with the exception of Glanton Hill (which may be avoided), the same favourable description is continued to Whittingham; but from this place, over Rimside Moor, to Weldon Bridge, the road is unfit for wheel-carriages, so that it was necessary to make a complete change of line from the north side of Glanton to Weldon Bridge, and to continue the same to Morpeth, by doing which a suitable mail-coach road may be obtained.

GENERAL SUMMITS AND DISTANCES.

DIVISIONS.	SUMMITS.		DISTANCES from Edinburgh.			
	Old.	New.	Old.		New.	
	Feet.	Feet.	Miles.	Yds.	Miles.	Yds.
Soutra Hill above Berwick Quay -	1,184	1,180	29	638	29	110
Whitburn - - - - - -	741	741	18	46	17	638
Greenlaw - - - - - -	559	548				
Coldstream Bridge - - -	61	61	13	286	11	484
Two Miles South of Wooler -	336	279				
Glanton Bank - - - -	518	331	22	418	21	630
Whittingham Loaning - -	313	182				
Landchild Hill - - - - -	428	221				
Rimside Moor - - - - -	816	607				
Weldon Bridge - - - - -	149	149	9	472	8	1,606
Lunden Hill - - - - -	461	382				
Morpeth Bridge - - -	85	85				
Catch Burn - - - - -	- -	- -	1	826	1	686
			93	926	89	634
To London - - - - - - - - -					283	854
Edinburgh to London, by Coldstream and Wooler - -					372	1,488

Old Rates of acclivities, 1 in 7, 8, 9, 10, &c.
New - ditto - 1 in 21, 24, 28, 30.

Such are the distances, supposing that the present road between Morpeth and London is left unimproved; but as ten miles may be saved south of the Trent, the distance between Edinburgh and London, by Coldstream, would only become 362 miles 1,488 yards.

BERWICK ROAD.

When the Wooler and Coldstream road survey was made public, the towns situated on the present coast-road, and persons interested in the adjacent parts, were alarmed, and they transmitted a strong memorial to the Treasury, urging the propriety of a survey being made of the coast-road, with a view of improving and shortening it; and this produced such an instruction to me as was desired.

After carefully examining the whole of the existing road from Edinburgh, by Haddington, Dunbar, Berwick, Belford and Alnwick, to Morpeth, I found that, in preserving the intercourse through the above-mentioned places, no material departure from the present road was practicable, yet that, on account of its imperfect state, nearly the whole required to be re-made, and much of it upon fresh ground. After making accurate maps and sections, taking advantage of every shortening that could with propriety be adopted, the saving in 108 miles 1,628 yards amounted only to 5 miles 648 yards, leaving the improved road between Edinburgh and Catch Burn, near Morpeth, 103 miles 980 yards, which is 14 miles 346 yards more than the Wooler and Coldstream line. But if my new section was realized, the acclivities would become commodious, instead of being, as at present, frequently unfit for wheel-carriages.

LONDON TO EDINBURGH.

SOUTHERN DIVISION.

The intercourse between London and Dublin being completely established, and the perfected road having also proved a great local advantage to the counties through which it passed, the example produced a desire of obtaining a line of similar road between London and Edinburgh, equally perfect; and numerous applications having been made to this effect, I received instructions from the General Post Office (March 1825) to make surveys between London and Morpeth, in connection with the surveys already described between Morpeth and Edinburgh.

At present the mail-coach goes by Ware, Royston, Huntingdon, Alconbury-Hill, Grantham, Newark, East-Retford, York, Durham and Newcastle. Another road, more generally travelled, passed by Barnet and Hatfield, joining the other road at Alconbury-Hill, when they proceed together through Newark to East-Retford, and north of that place, by Doncaster, Boroughbridge, Northallerton, Durham and Newcastle-on-Tyne.

A strait line drawn between London and Morpeth passes through or very near to Hatfield, Welwyn, Hitchin, Kimbolton, Thrapston, Newark, East-Retford, Thorn, Selby, Snaith, York and Newcastle.

South of the Trent, Royston is 12 miles, Alconbury-Hill 9 miles, and Stamford and Grantham 5 to 8 miles to the eastward of the above-mentioned line; while, north of the Trent, Wetherby, Boroughbridge and Darlington are about 7 to 9 miles westward of it. Besides these great deviations from a strait direction, the road in many instances

presents a succession of hills, too steep for the present rapid rate of travelling. Under such circumstances it was my duty to find a remedy for such radical defects; and after examining the features of the country in sundry directions, and making a careful comparison of the merits of various lines which had been suggested, I selected the following plan. Having already stated, that between London and Morpeth, Newark-upon-Trent is situated exactly upon the direct line, I found that the best practicable road to the latter place was by proceeding from London, by Barnet, to Hatfield, Welwyn, Hitchin, to Shefford, and near to Bedford; thence by Kimbolton, Thrapston, Oundle and Oakham, and by Long Bennington, to Newark. By this means ten miles in distance were saved, and an equal population accommodated, while the proposed line of road was remarkably favourable.

Between Newark and Morpeth, the road usually travelled is by Wetherby, Boroughbridge and Darlington, from seven to nine miles to the westward of a strait direction, whereas York is not quite three miles to the eastward of it. I therefore left the present road at East-Retford, and proceeded by Thorn, Snaith and Selby, to York, with nearly a direct and level line. From York to Newcastle, whether an improved line is taken by Northallerton and Durham, or by Stockton, and avoiding Durham, the distance was found to be nearly equal.

COMPARATIVE DISTANCES.

	Miles.	Yards.
The present Road from London through Ware to Morpeth -	285	810
Ditto - - - as it may be improved - - - - -	277	1,612
Ditto - - - by Barnet and Hatfield to Morpeth - -	289	590
Ditto - - - ditto - as it may be improved - -	279	1,461
New Line by Shefford and Newark, and improving present Road North of the Trent - - - - - - -	273	548
New Line by Shefford and Newark, and by York and Northallerton - - - - - - - - - - -	273	1,063
New Line by Shefford and Newark, by York and Stockton -	273	1,553

Upon the whole, it appears that between London and Edinburgh 26 to 30 miles in distance may be saved, according to the line adopted; and further, that by avoiding or improving acclivities, and making a perfect road, the shortening of time in travelling may be estimated at four hours.

The communications between London and Edinburgh, along the eastern side of the island, have thus been thoroughly investigated, and great care has been taken to shew distinctly in what manner they may best be shortened and improved; by all which it appears, that a mail-coach road of the most perfect construction, and in nearly a strait line from London, by Barnet, Shefford, Newark, York, Newcastle, Morpeth, Wooler and Coldstream, to Edinburgh, may be reduced to 362¾ miles; whereas the present hilly and incommodious road is at least 391½ miles. But no authority less influential than that of Parliamentary Commissioners must be expected to accomplish an improvement on so large a scale.

TEWKESBURY BRIDGE.

[*See* Plate 81.]

The town of Tewkesbury is situated on the eastern side of the river Severn, at its confluence with the Warwickshire river Avon, about eleven miles above the city of Gloucester. The surrounding district is rich and populous, but being intersected by a large navigable river, without a bridge in the immediate vicinity of Tewkesbury, the intercourse was very imperfect; and this being the only market-town on the bank of the Severn without a bridge, the inhabitants, in the year 1820, resolved to remedy this defect, and accordingly applied for and obtained an Act of Parliament, with power to construct a bridge, and proper approaches, the expense to be replaced by a bridge-toll.

The trustees under the new Act procured a plan, consisting of three iron arches, and proceeded to carry it into effect; but before one abutment was built up to the level of the ground, a misunderstanding took place with the architect, and, after much altercation, all parties interested solicited me to undertake the completion of the bridge; to which request, considering the confused state of the affair, I did not accede without reluctance.

The situation selected for the bridge is about half a mile above the confluence of the Avon and the Severn, under a headland named the Mythe-Hill, adjacent to the Worcester road. At this proposed site I caused the bed of the river to be proved by boring, when it was found to consist of alluvial matter to a great depth. Such being the case, and also the facility of barge-navigation on the Severn being important, I considered it unadvisable to construct a bridge of three arches, and therefore prepared a new design for one cast-iron arch, 170 feet span, which I found would embrace the whole breadth of the river, and produce no impediment to the navigation.

The masonry of the abutments was laid at the depth of six feet under low-water level, upon strong wooden platforms, encompassed by sheet-piling about ten feet deep. The abutments were carried to sixteen feet above low-water, which, allowing three feet of masonry to receive the cast-iron springing-plates, determined the lower edge of the large ribs to be thirteen feet above low-water level, great floods having been known to raise the water 18 feet.

The form of the masonry-abutments, and also of the iron arch, will be sufficiently evident by the Plate; but as I deem this to be a good specimen of a large cast-iron arch, I shall state the following particulars respecting it.

The span of the arch (or chord-line between the abutments) is 170 feet; its rise is 17 feet, or one-tenth of the span; the breadth across the soffit is 27 feet, that is, 23 feet for carriage-way, and 3½ feet on each side for foot-passengers. The iron arch consists of six main ribs, each three feet in depth; the outer ribs are 2½ inches, and the four interior ribs 2 inches in thickness. They are cast in lengths of 22 feet, and are connected and stiffened at each juncture by grated cross-plates, three feet in depth and two inches in thickness, to which they are severally screwed. The whole of the ribs so joined in one arch are placed upon springing-plates, three feet in breadth and four inches in thickness, carefully embedded in the masonry of the abutments; all these main ribs are covered on their upper surface with grated plates, one inch in thickness; and upon the six ribs thus connected into one frame are placed perpendicular lozenge-framing, to support the roadway bearers, which are connected by wrought-iron bolts (rods), or cross-ties, one inch and a half in diameter, passed through cast-iron tubes, with flanches adjusted to the lozenge-frames, and retaining them in a perpendicular position, while the wrought-iron bolts, being screwed to the outer ribs of the bridge, prevent them from bending outwards, and the interior of the spandrils are further secured by diagonal braces. Upon the top of the lozenges, that is, over each of the six ribs, bearers are fixed to receive the roadway plates, which are 4½ feet in breadth, and one inch in thickness, with flanches four inches in depth at each juncture, by which they are screwed together. Upon the road-plates are skirtings to retain the gravel of the footpaths, which are also provided with flanches to receive the bars of the side-railing. The whole structure is of the best Shropshire iron, commonly called "No. 2." The iron arch was furnished from the foundry of Mr. William Hazledine, of Shrewsbury; the masonry of the abutments, and the earthen mounds which formed the approaches, were creditably com-

pleted by Hugh M'Intosh. This bridge was commenced in March 1823, and finished in April 1826. The cost of the iron-work was £.4,500; of the masonry of the abutments, embanked approaches, and land-arches, the cost was £.10,000.

The peculiar feature of this bridge is the masonry of the abutment-wings, which, after being carried up solid three feet above the springing-plates, is then composed of tall, narrow Gothic arches, which not only give the whole bridge a light appearance, corresponding with that of the iron arch, but also afford an enlarged passage to the high river-floods, which sometimes occur, and might otherwise seem to endanger the bridge.

GLOUCESTER OVER-BRIDGE.

[Plate 82.]

The city of Gloucester, which justly boasts of Roman antiquity, is situated on the eastern bank of the river Severn. It is said to have been taken from the Britons by Ceaulin, the first king of the West Saxons, about the year 579, and in the ninth century the Danes had possession of it. About the middle of the eleventh century, the building of the cathedral was commenced by Aldred, Bishop of Worcester (afterwards Archbishop of York); and finally, Gloucester was made a distinct bishopric by Henry VIII. In what manner the communication west of the Severn was maintained in early times we are not informed. The bridges are known to have been built in the reign of Henry II., son of the Empress Matilda, who built the great stone bridge at Rouen, imitated in London Bridge by her grandson, King John. The first of these bridges was in use till the time of our Queen Elizabeth, the second endured till our own time, and was not then removed from any decay of the bridge itself.

About a mile and a half above Gloucester, the river divides itself into two branches, forming an island about two miles in length and three-fourths of a mile in breadth. The public road leading to Hereford, and also to Monmouth, crosses the lower part of the island, and consequently both the streams; on that next the city was a bridge of five arches; over the western stream was a bridge of eight arches. Both streams are navigated by barges of from 70 to 80 tons burthen, with masts which are lowered on occasion. Those having business at Gloucester arrive there by the eastern channel; but the general intercourse between the upper Severn and Bristol is by the western stream, that being the larger channel, and more easily navigable.

These bridges, having been built upwards of 600 years, and merely for carrying the roadway, their many piers, and low, narrow arches, were very inconvenient obstructions to navigation. At high tides, and in river-floods, the arches were either quite impassable, or extremely dangerous; and as intercourse by land increased, the narrowness of the roadway became inconvenient for wheel-carriages. On account of the low surface of the island of Alney (being frequently overflowed), an artificial causeway is carried from bridge to bridge, at the height of five or six feet above the meadow, supporting a roadway 28 feet in breadth.

The want of accommodation was, of course, most sensibly experienced at the bridge next the city, called the Westgate-Bridge, which, being within the jurisdiction of the corporation, was, in the year 1806, ordered to be removed, and replaced by a new bridge, more suitable to the improved state of the city. This was accordingly done; and in place of five arches, the whole stream now passes through one arch of 90 feet span, supporting a roadway 34½ feet in breadth. No care

was omitted to render the edifice substantial; yet, on account of the weak quality and depth of the alluvial matter upon which the abutments are founded, it was not, until 1828, judged advisable to place stone parapets on the new bridge; and although some trifling movement was perceptible in the year 1832, there is now reason to expect that the whole has acquired a solid bearing, and will long remain a handsome bridge. It was designed and built under the direction of Mr. Smirke (now Sir Robert Smirke), one of the most eminent architects of the present day, and cost £.45,000, repaid by a toll, which ceased in 1828.

The bridge upon the western and largest branch of the river (as has already been mentioned) consisted of eight arches; the three next the eastern abutment were each of 15 feet span; the fourth was 24 feet; the fifth, 20 feet; the sixth, 16 feet; the seventh, 11 feet; and the eighth (next the western side), of 18 feet span. The second pier from the eastern abutment was 18 feet thick; the third from the western side 20 feet; the others were 9 and 12 feet; so that the width between the abutments being 245 feet, 108 was occupied by piers, leaving no more than 137 feet for water-way. The four arches on the eastern side, and the third on the western side, were of brick, and appeared to be modern; the other three were part of the original stone bridge. Over the latter, the width between the parapets was only 13 feet; upon the three eastern it was 15 feet. This bridge was maintained at the expense of the county, as distinguished from the city of Gloucester.

From this description it will be evident that the roadway over the bridge, as also the navigation under it, were very incommodious, so that it was not without good reason that the magistrates, in 1825, determined upon a new bridge. They, in that year, applied to me

for a design of suitable dimensions, which should, in all respects, correspond with the increase of intercourse, and the character of modern improvements.

Having, after full deliberation, recently constructed a cast-iron bridge of 170 feet span (which embraced the whole breadth of the river), near the town of Tewkesbury, only 10 miles above Gloucester, I was convinced that an arch of similar dimensions was of sufficient extent for two-thirds of the divided stream, at the island of Alveney, and prepared a design accordingly; but the magistrates gave preference to a design for a stone bridge of 150 feet span, which I had also prepared under their direction. This opening of 150 feet is sufficient for the water-way and navigation, the cast-iron arch having been made 170 feet span in order that the ribs near each abutment might not be struck by barges, timber, and other floating matters.

For this bridge of one stone arch I introduced a form which, although a novelty in England, had, in 1768, been employed by an eminent French architect (Mr. Perronet) in a bridge of five arches, of 128 feet span each, over the river Seine at Neuilly; and this appeared to be peculiarly applicable to the Severn, where the upland floods are considerable. By referring to the Plate, it will be seen that this is accomplished by making the general body of the arch an ellipse, 150 feet on the chord-line, and 35 feet rise, while the voissoirs, or external arch-stones, being in form of a segment, have the same chord, with only 13 feet rise. This complex form converts each side of the vault of the arch into the shape of the entrance of a pipe, to suit the contracted passage of a fluid, thus lessening the flat surface opposed to the current of the river whenever the tide or upland flood rises above the springing of the middle of the ellipse, that being at four feet above

low-water, whereas the flood of 1770 rose 20 feet above low-water of an ordinary spring-tide; which, when there is no upland flood, rises eight or nine feet.

The design having been approved, I prepared working drawings, and a detailed specification. The works were advertised, and the magistrates accepted the proposals of Mr. John Cargill, a contractor of great experience and respectability, who had, for upwards of twenty years, been employed upon public works under my direction.

Practical operations were commenced in July 1826, on the eastern or Gloucester side, where the stratification of sub-soil is as follows:—

	Feet.
1.—From the surface of the meadow downwards, rich Loam -	11
2.—A bed of soft blue Silt - - - - - - - -	12
3.—A layer of Peat Moss - - - - - - - -	5
4.—Brown Clay - - - - - - - - - -	5
5.—Strong coarse indurated Gravel - - - - - -	3
6.—Finer Gravel or coarse Sand - - - - - - -	8
	44

The foundation was placed upon the indurated gravel, which was laid bare, in expectation of its being solid rock, the auger having been stopped by a stone in boring. If that had not happened, the masonry foundation would have been laid upon the brown clay, the surface of which is five feet deeper than the bed of the river: the foundation is now in fact 10 feet deeper. A space of 40 feet square was therefore excavated, to the depth of 33 feet below the surface of the meadow, and for the purpose of protection it was necessary to construct a very substantial cofferdam, as the floods sometimes rose six feet above

the river-banks, so that for security the side of the cofferdam, as well as its returns into the natural banks, was formed of piles of Memel timber, 30 to 32 feet in length, with a space of 5 feet between the outer and inner circumference of piles, which was filled with clay, worked into water-tight puddle. To keep up the earth around the excavation on the solid bank, one row of piles sufficed. A head of 30 feet depth of water pressing upon this cofferdam required all Mr. Cargill's experience and ingenuity to resist it; but so effectually did he provide against cofferdam defects and accidents, that a steam-engine of eight-horse power had no more than half employment. When the excavation reached the before-mentioned gravel, and its bottom had been made perfectly level, a course of large and flat-bedded rubble-stone was laid over the whole space; upon this the timber platform was carefully bedded. It consists of thirteen Memel logs made strait and level; the length of them, laid at right angles with the stream, is 37 feet, and of those up and down the stream, 40 feet. The logs are equi-distant, and the square spaces between them are filled with rubble-masonry, well grouted. These logs or sleepers, thus prepared, are covered with four-inch beech-planks, planed, closely jointed, and spiked to the logs, thus forming a level platform, 40 feet by 37; and upon this platform the masonry is founded. The stone for this part of the structure was brought down the river, from quarries at Highley and Alveley, six miles above the town of Bewdley. They vary in thickness from 14 inches to 2 feet; in weight, from one to three tons. They were squared on all sides, and well bedded; every course was brought to a level, and grouted, before the next course was set. The same stone was used up to low-water mark, afterwards for backing only; its quality was strong and durable, but the stone for all the external masonry is from the quarries of Coleford and Quitchurch, in the Forest of Dean.

The abutment on the west side of the river was equal in dimensions, and perfected in all respects like the other, only that the gravel was found at 27 feet under the meadow, instead of 33 feet, and the ground in general was much firmer.

The wing-walls at the immediate back of the abutments are founded at from eight to ten feet below the surface of the meadow. At their extremities, from two to three feet, they are seven feet thick at the foundation. These wings, having chiefly to support the earthen mounds of the embanked approaches, it was unnecessary to incur the expense of piling and platforms; but on the eastern side, the alluvial matter upon which they are placed is so soft, that they have sunk considerably, so that, instead of conducing to the support and stability of the masonry of the abutments, the wings have receded, created fissures, and tend to weaken it. I therefore take blame to myself for the injudicious parsimony of omitting the piling and platform, and now mention this as a useful caution to practical engineers. On the western side, the ground was sufficiently firm, and the wing-walls and retaining-walls remain immovable.

One of the chief objects to be attended to in the construction of large stone arches is the timber-frame or centering which supports the whole masonry of the arch, until it is keyed. In the present case, as Mr. Cargill (who had contracted to complete the bridge for a certain sum) was a person experienced in such operations, he was left at liberty to construct centering agreeably to his own design, subject to my approbation. It was quite safe and substantial; and from the engraving [Plate 62], its form, which is very simple, will be distinctly comprehended. Instead of a complete trussed framing, depending upon the two extremities, Mr. Cargill supported his centering by six parallel

rows of piles, fixed in the current of the river, each row connected by cross-braces and caps, and each supporting a rib, which formed the actual centering. Both the piles and ribs were further steadied by diagonal braces; and between the pile-caps and the superincumbent ribs, the wedges were placed, by which the centering was to be slacked or lowered after the masonry was keyed; and some of the spaces between the parallel rows of piles being 16 feet wide, the navigation of the river by barges proceeded without interruption.

An accurate engraving of the centering is given in Plate 63, and a detailed description of the making, framing, fixing and striking, will be found in a letter from Mr. Cargill, which I have inserted in Appendix (P.), being, in my opinion, valuable information to persons employed upon similar works.

The centering having been properly fixed, the masonry of the arch proceeded. Its magnitude and peculiarity of construction required all the experience and skill of the workmen; but the stones from the Forest of Dean were of such excellent quality, and the arrangements of Mr. Cargill so judicious, that the arch proceeded with as much regularity as if of the smallest span, and was completed without a single accident. The dimensions of all the parts being marked distinctly upon the engraved Plate, I shall only observe, that the depth of the arch-stones at the springing is 5½ feet, and 4½ feet at the key. The thickness of the abutments at the springing of the ellipse is 27 feet 2 inches, besides the wing-walls, which are 7 feet each; the spandril walls are 3 feet 6 inches thick, exclusive of the pilasters; the four interior longitudinal walls for support of the platform of the roadway are each 2 feet thick; the width of the carriage-way is 27 feet, with a footpath of 4 feet on each side of it.

When the centering was removed, and the whole weight of the arch left to press against the abutments, its crown sunk about two inches, and afterwards, from the before-mentioned receding of the eastern wing-walls, the arch suffered a further depression of eight inches, making, in the whole, 10 inches. The arches of the Neuilly Bridge, of only 128 English feet, sunk 13 inches when the centering was lowered, and afterwards 10½ inches more, making 23½ inches; and that the sinking of Gloucester arch of 150 feet span took place from the pressure upon the upper part of the eastern abutment, when deprived of the resistance of the wing-walls, is evident from the front not having sunk, and the courses of the stone facing towards the river remaining quite level. On the western side of the river, the abutment and walls, being upon firmer ground, remain unmoved.

Upon the whole, although the sinking of this large arch is small in comparison with what took place in M. Perronet's Neuilly Bridge, yet I much regret it, as I never have had occasion to state any thing of the sort in any other of the numerous bridges described in this volume; and I more especially take blame to myself for having suffered an ill-judged parsimony to prevail in the foundations of the wing-walls, leaving them unsupported by piles and platforms,—because if so secured, I am convinced that the sinking of the arch would not have exceeded three inches.*

* Mr. Telford was perhaps misled into too much reliance on the superficial foundation of the eastern wing-walls of this bridge, by opportunities which had occurred to him of seeing the shallow foundation of very ancient massive structures. He used to speak of an old castle tower removed under his direction, which had been placed on the surface of a meadow, into which it had merely sunk or subsided by pressure about two feet; and the admirers of our magnificent specimens of church architecture would shudder

The expense of this bridge and its approaches was £.43,500. 9s., being less by £.1,500 than the expense of the earlier Westgate Bridge, of 90 feet span.

PROPOSED LONDON AND BIRMINGHAM CANAL.

Having bestowed much pains upon making a perfect map and section of an intended canal between London and Birmingham, I deem it useful to insert the particulars.

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if they knew how slight in some instances are the foundations of a fabric consolidated by its own vast weight.

Proof may be seen in masonry at least 1,400 years old, that even the Romans, who usually far surpassed modern architects in the solidity of their substructions, did sometimes venture too far into the opposite extreme. The quadrangular camp or station of Castle-Burgh (near Great Yarmouth) is fortified by walls so deeply founded as to have withstood in a great degree the undermining attack of river floods, and of such excellent masonry, that part of the defences still remain of their original height. At some after period, towers of the same external appearance as the wall, have been added as projections from its sides and corners; but these supplementary additions are without foundation, being supported by their connection with the wall, into which they are fixed by means of tye-stones. Thus the towers are built into the surface of the wall, which must have been displaced for that purpose,—and the consequence has been, that in some instances the tower has torn down the wall; in some instances the wall still supports the appendant tower; and in one instance (at the S. E. angle) the force of weight and workmanship is so nicely balanced, that the tower slopes from the wall, and displays to modern eyes the exact nature of the attempted juncture. Another of these towers (on the north side of the camp) lies prostrate, displaying its entire bottom, which, having been placed originally on a layer of durable mortar, bears indubitable marks of the rough planks on which this tower was built on the surface of the soil.

But Mr. Telford would have erred in deducing from his instances of perpendicular pressure the sufficiency of a wing-wall, which is in the nature of a buttress, to assist lateral pressure, in this case of a very large and flat arch; or perhaps he thought himself in this instance justified in relying on the unyielding resistance of the abutments, which are described as being of remarkable solidity and very deep foundations. The repose of these wing-walls or of ten times their mass on the meadow surface, might be unquestionable, but their lateral resistance was not such as to bear unmoved the pressure communicated by the arch through its eastern abutment, and the entire structure is thus rendered imperfect.

The Act for the Birmingham and Liverpool Junction Canal having been passed in 1826, and practical operations commenced, it was evident that in a short time a direct communication by water, and by one continual descent, would be obtained from Birmingham to Liverpool, and also to Manchester; but that, from Birmingham to London, the canal communications were either very circuitous, or retarded by many locks. Passing by way of Fazely and Coventry to Braunston are 54 locks, and by the Warwick and Napton Canal, 77 locks, to be descended and ascended; whereas, by a new line proposed by me along the summit, between the Trent and Avon valleys, the intercourse might be accomplished by passing 20 locks only.

In 1827 a Bill was brought into Parliament, under the title of "the London and Birmingham Canal;" but a considerable land-owner having objected to a particular part of the line, as approaching too near a family residence, the Bill was withdrawn, in order to remove this objection. In 1828 another similar Bill was introduced, but at an early stage of the business the death of a principal contributor deranged the subscription list, and the Bill was again withdrawn.

In order to render the intercourse perfect, I had proposed that the locks and bridges should admit barges of 14 feet breadth of beam, being the same as the Grand Junction Canal, in order that the same boat might pass between London and the Staffordshire coal and iron district. I intended also, in order to accommodate a great trade, that the locks should not be placed singly, but in pairs, and that on each side of the canal should be a towing-path.

The discussions upon this project having obliged the Oxford Canal Company to take into consideration the very crooked and imperfect

state of their navigation between Braunston and the place where the new canal would join it, they were convinced of the propriety of obtaining Parliamentary authority for improvements in this distance, which was accordingly done, and practical operations commenced. Indeed, upon consideration, they became sensible that the scheme I had proposed was the only means of extricating them from some serious difficulties in which they were involved.

ENGLISH AND BRISTOL CHANNELS SHIP CANAL.

Having formed a regular plan and section, and assisted in carrying a Bill through Parliament for a Ship Canal between the English and Bristol Channels, I am induced (although it has not been carried into effect) to record the progress made, and state the facts which have been ascertained, as they may prove useful, in case public attention should hereafter be drawn toward a similar project.

It is evident that between the great estuary of the Severn, called the Bristol Channel, and the sea that washes the southern shore of the kingdom, is a body of land, comprehending the counties of Devon, Cornwall, and a part of Somerset. This south-west portion of England is 150 miles in extent, and at the town of Bridgwater the isthmus (so to speak) is no more than 44 miles in breadth, and thus forms a peninsula jutting into the Western Ocean, which at its extremity, denominated the Land's-end, is from situation much exposed to storms, which render the communication between the south-west part of England, Scotland and Ireland, tedious, and not unfrequently dangerous. On the northern side of the Bristol Channel (which is from 15 to 35 miles in width) lies South Wales, a mountainous tract, with extensive valleys abounding with coal and iron, now worked to an unprecedented

extent; while the southern part of England, being void of these important minerals, is supplied either from South Wales or the counties of Durham and Northumberland, while South Wales is supplied with foreign produce chiefly through the port of London.

Thus circumstanced, it has long been considered desirable to open a navigable communication between the English and Bristol Channels, across the before-mentioned isthmus, adjacent to Bridgwater.

In 1769 Mr. Whitworth, an eminent engineer, surveyed this tract of land for a canal of small dimensions, as was usual in that early state of inland navigation. The line selected by him proceeded from the river Parrot, through the town of Bridgwater, and up the flat meadow to Langport; from whence, passing the summit level, it descended to the sea-shore at the village of Seaton. This project was condemned, on account of its cutting up rich meadows, interfering with mills, and incurring the necessity of transhipment of sea-borne cargoes.

After an interval of forty-four years, in 1811 the scheme was revived, and Mr. Rennie made a survey, plan and section of a canal for vessels of 120 tons. This canal commenced in the river Parrot at Coombich-reach, and following nearly the same line as laid out by Mr. Whitworth, was resisted on similar grounds.

In the year 1822, Mr. James Green, of Exeter, at the instance of Lord Rolle and others, made a survey and report, in which it was recommended to obtain the desired communication by means of level reaches of canal, joined by inclined planes, the canal portions to be 22 feet wide at top-water, 12 feet at the bottom, and 3 feet 6 inches deep; but this plan was never seriously pursued.

In 1824, a renewed spirit of speculation being prevalent, the project of a ship canal was revived, a company was formed in London, and I was employed to re-survey the line, to point out any improvements that might occur to me upon Mr. Rennie's plan, and to provide a canal for vessels of 200 tons. To accomplish this object, I intended the locks to be 125 feet long, 30 feet wide, each to rise 8 feet. The canal was designed to be 95 feet wide at top-water, and 15 feet deep. The total distance between the northern and southern coast is 44 miles 5 furlongs, and the height of summit-level above high-water, 231 feet. On the coast of the English Channel, instead of Seaton, I proposed a harbour at Beer-Cove, formed by protecting piers; from whence, after passing immediately above Seaton village, and ascending along the western side of the valley, I extended the summit-level from 2½ to 12½ miles in length; and on the northern coast, instead of terminating in the river Parrot at Coombich-reach, I carried the canal to the sea-shore at Stolford, and there placed protecting piers and floating-docks. The supplies of water were, in all cases, furnished on the summit-level by one navigable feeder from the river Axe, on the eastern side, and another from the Yarty, on the western side. The estimated cost of this canal, and of the two Sea entrances, was no less than £.1,712,844. [Appendix (Q.)]

As a civil engineer, I considered my duties only to extend to the practicability and expense of the canal and harbours; in what regarded nautical matters, I relied on Captain George Nicholls,* who, having long commanded a ship in the East India Company's service, had acquired great experience in his profession, and from his able reports, and the annexed Table, taken from documents laid before Parliament,

* Mr. Nicholls is now one of "The Poor Law Commissioners;" an appointment which, in its circumstances, has diffused a general expectation of the efficiency of that Board.—T. T. August 1834.

it appears that the intercourse around the Land's-end is very great; and that the saving of time, expense and risk, if a ship canal were made across the isthmus in the direction laid down by me, would be of essential advantage to the public, and might probably produce an ample return to the subscribers.

TABLE.

NUMBER of VESSELS which passed the LAND'S-END in 1823.

[From a Parliamentary Return.]

	BRITISH.		FOREIGN.	
	Vessels.	Tons.	Vessels.	Tons.
From the West Coast of England to S. and E. Coasts	2,833	236,876		
From S. and E. Coasts of England to the W. Coasts	2,255	173,797		
From Ireland to the S. and E. Coasts of England	1,103	99,299		
From the S. and E. Coasts of England to Ireland	419	43,974		
From the W. Coasts of England to Foreign Ports	746	85,627	685	105,690
To the W. Coasts of England from Foreign Ports	725	92,393	608	86,111
From Ireland to Foreign Ports	93	8,112	219	37,403
From Foreign Ports to Ireland	291	29,118	265	32,030
	8,465	769,196	1,777	261,234
	Average Tonnage, 91 Tons.		Average Tonnage, 147 Tons.	

After due deliberation, the Committee of management resolved to proceed; and having brought a Bill into Parliament accordingly, an Act was obtained in the 6th of Geo. IV. Session 1825. But at this time the depression consequent on the excessive spirit of speculation supervened, and this enterprise, as well as many others, was arrested in its progress from the same cause, and has not since been revived.

METROPOLIS WATER SUPPLY.

The supply of the metropolis of the British empire with pure water being an object of the first importance, I consider it a duty towards the public to record the means of improvement which have been in preparation during several years in which I was employed in investigating this subject.

The extension of gas-works and other establishments which discharge nauseous or deleterious substances into the river Thames, the change which has taken place in the habits of the people, involving an enormous increase of consumption of water, and the imprudent conduct of the rival water-work companies which supply the metropolis, gave some colour to the exaggerated statements of artful and mischievous persons, who were eager to promote contention, and inflame the passions of the inhabitants,—which were raised to such a height regarding the supply of water, that Government found it advisable to appoint a Commission, in which I had the honour to be named with Dr. P. M. Roget, and William Thomas Brande, Esq., for investigation of the subject; and the Commissioners, after having bestowed much labour in the examination of evidence, made a Report, which is inserted in the Appendix (R. 1.)

This report by no means satisfied the inhabitants of the metropolis, so that I was afterwards employed by the Treasury (on the suggestion of Sir Francis Burdett) to investigate the practicable sources of pure water, and the levels by which it might be brought to the metropolis, on both sides of the river Thames. This investigation proved tedious and expensive, but the result was so far satisfactory as to prove the possibility of obtaining an ample supply of excellent water, though at very great expense, from the north and also from the south side of the

metropolis. [Appendix (R. 2.)] I ought to add, that this project, although not likely to be realized, has stimulated the exertions of some of the water companies in such manner that the eastern portion of the metropolis is now supplied with pure water from the river Lea; and that the managers of the Chelsea Water-works, [Appendix (R. 3.)] peculiarly obnoxious to popular clamour (from their source of supply being solely the river Thames) have succeeded in establishing a filtration on so large a scale, and so effectual, that the inhabitants of Westminster no longer have recourse for pure water to their wells and public pumps, the supply from the river Thames by the Chelsea Water-works being preferred for all purposes.

SUPPLEMENT.

THUS ends the Narrative of Mr. Telford, as left by him at his death; and it is uncertain whether, had his life been prolonged, he would have added to it any particulars of the only work which he afterwards commenced, under circumstances which scarcely permitted him to plead his wish for retirement from active life.

The harbour of Dover became more and more important in proportion as intercourse with the Continent increased, after the Peace of 1815; and the occasional obstruction of the harbour-mouth by a temporary accretion of shingle from the westward was felt as a national inconvenience which ought not to be tolerated, if remedy could be

found in the advanced state of civil engineering, to which no man had contributed more largely than Mr. Telford. Add to this, that the Duke of Wellington, after retiring from the helm of the state, continued to hold the office of Lord Warden of the Cinque Ports, and, with his characteristic energy, determined on a further effort to insure access at all times to the interior of Dover Harbour. The winter of 1833-4 had produced an unusual obstruction during several weeks, and towards the end of January 1834, the Duke desired Mr. Telford to visit Dover, and, after obtaining all the local information which could be imparted by the resident engineer, the harbour-master and pilots, to give his opinion as to the most advisable mode of proceeding.

Applicable to the purpose of clearing the harbour-mouth, exists about twenty acres of back-water, retained by shutting at high water a navigable sluice, by which shipping are admitted to the inner basin. In the wall of separation between the outer and this inner harbour are placed other large sluices, always opened at the most efficacious time of ebb-tide; but the torrent of water thus produced, however powerful at its exit from these sluices, was weakened to that of a river stream in a passage of five hundred yards to the harbour-mouth, where only it could act on the bar of shingle advantageously. This error became known gradually; and Mr. Telford found that part of the back-water was already carried by an iron pipe behind the harbour wall to a small reservoir at the south side of the harbour entrance, and discharged by three culverts directly upon the bar of shingle, with a tendency to push it into deep water, and thus to clear the entrance of the harbour. Mr. Telford, therefore, recommended a decisive increase of this beneficial influence, and forthwith made a report to that effect: it is printed in the Appendix (S.), as well as a succinct statement, which Mr. Walker (who was desired by the Duke of Wellington to take charge of Dover

harbour at Mr. Telford's death) has been so good as to communicate; whence it appears, although the task has been more difficult than was anticipated, that Mr. Telford's plan is likely to be finally crowned with success.

The termination of Mr. Telford's life now approached: personally he was of athletic mold, and, until the age of seventy, had never suffered any serious illness. At that time, in the year 1827, he was afflicted by a severe and painful disorder, at Cambridge; and, though he recovered health after a considerable interval, his nearest friends observed with regret that much of his former energy had disappeared, and he became liable to bilious derangements of dangerous character. These became constitutional, and recurred in the spring and autumn of 1832 and of 1833; again in the spring of 1834; and on the 23d August 1834, commenced the attack which, after affording delusive expectations of his recovery, terminated fatally on the 2d September of that year.

No man was further removed from vanity or ostentation than Mr. Telford, and he intended to be buried in the parish church of St. Margaret, Westminster; but the feelings of the living, rather than of the dead, are to be consulted on such occasions; and the institution of Civil Engineers, who justly deemed him their benefactor and chief ornament, urged successfully upon his executors the propriety of interring him in Westminster Abbey; and the most eminent of that body (Mr. Walker especially, who succeeded to the presidency), together with Mr. Telford's particular friend, Sir Henry Parnell, M.P., attended the funeral, walking from the near residence of the deceased in Abingdon-street. The exact place of interment, near the middle of the nave, is marked on the pavement with the name of Telford, and the date of 1834.

The intimate connection of Mr. Telford with the institution of Civil Engineers is a material feature in his biography, but such a one as his dislike of personal intrusion on his readers did not permit him to record in his own narrative. In the beginning of the year 1818, a small society was formed, consisting partly of young men (now of mature age), who had been educated to civil engineering by Mr. Telford, partly of mechanicians (a closely-connected branch of art), and of a few other lovers and mutual imparters of useful knowledge. Those members of the society who personally knew in Mr. Telford his readiness of access, and his delight in unreserved interchange of rational conversation, proposed to the society, in the beginning of 1820, to invite Mr. Telford to patronize their institution by taking on himself the office of President. Till that time, the existence of the society was unknown to him; but he did not the less perceive in it much promise of public benefit, and entered upon his new office on the 21st March 1820. [Appendix (T.)] About this time Mr. Telford had begun to withdraw himself from undertaking professional engagements in addition to those in progress; henceforth he might be called a regular inhabitant of the metropolis, and so sedulous was his attention to the society over which he presided, that no other member attended the weekly meetings with so much regularity as himself; no member furnished so many appropriate books and documents to the small collection, which could scarcely then be dignified with the name of a *Library of Reference*, but which he justly deemed one of the essentials of the institution, and augmented it by his last Will with many valuable books, and a vast collection of documents, which from time to time had been subservient to his professional labours.

The last words of Mr. Telford's inaugural address contain a sentiment of more importance than is usually attached to it—" That talents and " respectability are preferable to numbers; and that, from too easy

"and promiscuous admission, unavoidable and not unfrequently in-"curable inconveniences perplex many societies." In fact, when the meetings of any public society cease to be the scene of animated conversation on the subjects of its association, it becomes a formal catalogue, in which members inscribe their names, usefully perhaps for their advancement in life, but without lively hope of improvement in any particular branch of knowledge. Widely different from this was the institution of Civil Engineers, especially when it was consolidated by Mr. Telford's acceptance of the presidency. He immediately established the practice of recording in a summary manner minutes of their conversations, which did not fail to excite in the members attention to every object, in refutation or support, which otherwise might pass unnoticed. Other societies may have adopted the same practice for the advancement of knowledge; but probably it is peculiar to the institution of Civil Engineers that such practice has continued from the acceptance of the presidency by Mr. Telford to the present time, and with such growing conviction of its utility, that these Minutes of Conversations are now printed annually, for the use especially of those members who are precluded by distance or professional engagements from frequent appearance at the weekly meetings.

In the year 1828, Mr. Telford exerted himself strenuously in obtaining a Royal Charter of incorporation for the Institution of Civil Engineers; after which they removed from their former apartments in Buckingham-street to the neighbourhood of Bridge-street, Westminster, and they have now again outgrown their residence, which is to be transferred to Great George-street; the vicinity of Parliament being almost essential to civil engineers for watching the progress of that peculiar but very important branch of legislation, afterwards carried into effect by them and by the auxiliary arts and manufactures, to which they impart

a skilful activity. Mr. Telford's rule of selection has not been violated; yet such has been the real advancement of the profession, that the society had increased to 200 members at the time of his death.

A collection of biographical facts of minor importance, and the marked traits of character which distinguished the late Mr. Telford, cannot be out of place in this Supplement, whether arising from diligent inquiry, or from an intimacy of thirty years' duration.

Thomas Telford was born in the parish of Westerkirk, in the county of Dumfries, on the 9th of August 1757, and died at his house, in Abingdon-street, Westminster, on the 2d of September 1834, being, therefore, rather more than 77 years of age at the time of his decease. His mother's name was Janet Jackson, and her care of his infancy and growing years was of the more importance, as his father died before the end of the year 1757, leaving his son Thomas an orphan. The mother survived till the year 1794. She always enjoyed the dutiful regards of her only son, who is said to have written all his letters addressed to her in printed characters, that she might read them herself without assistance. Telford's father was a shepherd in the pastoral district which divides the counties of Dumfries and Roxburgh, and the orphan received the rudiments of education at the Westerkirk parish school, in the summer season assisting his uncle as a shepherd boy. In this occupation bodily labour is not required; and young Telford, being furnished with a few books by his village friends, applied his acquired power of reading to very good purpose; indeed, it became a habit which always recurred when he was not otherwise too closely occupied in his profession; and it must not be forgotten in the history of his life, that he collected with diligence, and digested into elaborate treatises, for insertion in the Edinburgh Encyclopædia (in which he was a share-

holder), all that is known of Architecture, Bridge-building and Canal-making; and has thus presented to the public, in a regular form, his knowledge of theory, as sustained or corrected by his own extensive practice, recorded in this volume.

It might have excited a smile in many of his friends, and probably Telford himself thought so, as he never hinted at the fact,—that the earliest distinction he acquired in life was as a Poet!—nor does he seem altogether to have abjured the Muses even at nearly thirty years of age, when he reprinted at Shrewsbury a poem, descriptive of the early scenes of his life, entitled "Eskdale," which finds a place in the Appendix (U.)

His destination in life after boyhood was to become a stone-mason, as is sufficiently detailed in his own narrative, until he settled at Shrewsbury under the patronage of Sir William (Johnstone) Pulteney; a man of singular habits of life, approaching to penury, although he possessed a princely income. Yet was he not ungenerous or insensible towards merit, and his acuteness of mind at that early date penetrated into the principle which is now developed and adopted, of not transferring the property of others to a parish pauper, unless his absolute destitution is established by an unerring test.

Telford in his youth is known to have been tinctured with the then fashionable doctrines of Democracy, while the strong mind of his patron derided and detested the flimsy tissue, as might be expected from his penetration and experience. A dangerous rupture was once likely to ensue, when Telford rather improperly transmitted some of the political trash of the day under his patron's frank; but the latter pardoned him, after due animadversion.

In looking back to the beginning of the French Revolution, when Democratic opinions were almost universal among educated youth,—the source of an error, soon after eradicated by the horrors of the guillotine, is not unworthy of investigation. Custom, and perhaps good taste, has ordained that education shall mainly consist in acquiring a knowledge of the learned languages, and studying the classic authors of antiquity, who from their position uniformly favour republican principles as opposed to monarchy.

The Greeks despised and abjured the servile ceremonial of the Persian Court, preferring to it the incessant turbulence of their own democracies; and the Romans held in a kind of superstitious abhorrence the title of King, even after they had bowed their necks with complacency to despotic power, under the military title of Emperor. These popular fallacies of antiquity had not been detected and exposed, while they seemed to produce no bad effect, and the surface of ancient history had not then been penetrated by inquirers, who investigated the state of human society concealed under it. When ancient republics became sufficiently established to ensure the safe custody of the captive by walls and fetters, slavery came into use instead of indiscriminate slaughter of the vanquished enemy; and slaves, predial or domestic, soon constituted the majority of mankind. Thus the high-spirited patriots of antiquity, whom we assume as models of noble conduct, were all slave-holders, nationally or individually, and their patriotism, when closely examined, is found to be little else than an effort to obtain similar command over their equals by violence or treachery. So incessant were those attempts, that it is incidentally said, in the time of Alexander the Great, after he had humbled and pacified the Greek republics, that he restored to their homes 10,000 political exiles; many of whom, no doubt, had been whetting the dagger by which they hoped

to be restored to his native city, supported by domestic faction or foreign aid. Such were the strenuous patriots of classic Greece, such the hideous state of society infested by their cruelty and violence. Yet such was the mighty influence of education, that at the commencement of the French Revolution, resistance against any settled government was deemed laudable, because, forsooth, government did not form an exception to all other human arrangements, by having attained to absolute perfection; and the experiment of bestowing power without responsibility (the essence of all democracies), aggravated by its limited tenure, was tried in civilized France with a result which suffered by comparison with the atrocity of ancient proscriptions, and dispelled the illusion of the ardent spirits of the age.

Till these scenes had passed before his eyes, Telford was more than usually liable to classic influence, from the imperfect range of his reading, which seems to have been much confined to Plutarch and Rollin: the first tainted with the besetting sin of biographers, in favourable display of the motives and actions of each successive hero, even to self-contradiction, when a rival is afterwards to be introduced;—Rollin, an agreeable historian, doubly recommended to the favourable attention of Telford by also treating of the Arts and Sciences of antiquity; in which dissertations our then aspirant in architecture first beheld (in Rollin's plates) the graceful forms of Grecian temples, and read of the surprising excellence of their sculptors:—And how could he permit himself to believe that the countrymen of Pericles and of Phidias were not equally perfect in their political institutions? But after the horrors of the French Revolution, Telford silently abandoned politics to the care of those active citizens who spend their time in discussing what they rarely understand; and during the remainder of his life he never conversed on political topics, uniformly

endeavouring to change the subject of any conversation which had that tendency. In this kind of silent evasion from former error, we know, and some of us perhaps feel, that he was far from being singular.

Telford loved his profession, and was so energetic in any task before him, that all other motives became subordinate to it. He formed no matrimonial connection, and lived as a soldier, always in active service, without fixed habitation, until he had reached that age which our forefathers deemed the usual close of human life. Thus the acquisition and accumulation of property had always been a secondary consideration with him; he was even ingenious in discovering arguments why in certain cases he might act without reward*; and he was slow in increasing his rate of charge in proportion as his reputation and experience authorized such increase, which was always forced upon him as matter of necessity,—that is, of justice,—as regulating, in a considerable degree, the fair remuneration of his brethren in the same profession.

After his mother's death, Telford had few family connections to provide for; and although he was ready to help these, when occasionally in want of pecuniary assistance, yet he did not divide his property amongst them, having from experience formed a strong opinion against the removal of any man from his station in life. In the distribution of his professional patronage, as of his property, he had no temptation to

* Frequent instances occur in Telford's accounts, of his declining to receive payment for labour, and even expense, bestowed on abortive or unsuccessful speculations;—and when he was employed by Government in the improvement of the Highlands, he persuaded himself that he ought to promote a similar object of the British Fisheries Society, for whom he regularly acted in his profession, rejecting proffered remuneration. But the British Fisheries Society did not suffer themselves to be entirely outdone in liberality, and shortly before his death, they forced upon him a very handsome gift of plate, which, being inscribed with expressions of their thankfulness and gratitude towards him, he could not possibly refuse to accept.

swerve from the strict path of justice, so that a large proportion of the legatees named in his will are persons educated under his own eye in strict propriety of conduct, as well as in professional attainments. Telford's position both in public and in private life rendered him independent of favour or patronage; and he enjoyed the rare privilege of being his own master in the exercise of perfect impartiality, and of an undeviating adherence to what is abstractedly just and proper; his liberality was extended to all applicants who were recommended to him by merit, and indeed to many who could plead little more than their own imprudence; and these last received with his bounty that sort of kindly reprehension and advice most likely to be effectual when so administered. [Appendix (V.)]

The character of Telford, moral and social, might be over-rated, were not the above peculiarity of his situation taken into account; but man is a creature of position and circumstances, so that in the study of history, to appreciate character, without regard to the prevalent scale of morality by which a great man is surrounded, is indeed but a sorry fallacy, which refuses to take into account the practical law of human actions,—the degree of integrity or disinterestedness which is measured by the mutual conduct of contemporaries. The Duke of Wellington in our own age, and the Duke of Marlborough a century since, form perhaps the most perfect parallel which history has recorded; of equal sagacity and decision in the field of battle and in the councils of nations; equal in glory, and in resisting the ambition of France when she sought to attain domination over the rest of the family of European nations:—yet without scrutinizing too closely the frailties of a hero,—Who is not sensible that the slightest symptom of the faithless intrigues of Marlborough, or of his notorious rapacity, would now thrust Wellington, with all his greatness, out of the pale of English society?—And if we go back to

the age of the Tudors, the most upright statesman was not perhaps a better man than the least scrupulous statesman in the age of Marlborough. At an earlier date we perceive that injustice and violence were necessary for the self-preservation of the powerful baron; and the commencement of all European history tells of the mutual slaughter of barbarous tribes, till we are surprised that the race of man was not extinguished, and the earth left to the dominion of the less noxious animals of the forest.

But the most distinguishing trait of Telford's character was, that facility of benevolence which made him accessible to all, especially to foreigners, who resorted to him for information or advice; and this, added to his connection with the Götha Canal in Sweden, exalted his fame abroad as the first civil engineer in Europe, several years before he was acknowledged at home to hold that station. The Russian government consulted him frequently on various schemes of canal navigation and other improvements, and the younger Worontzoff, who might be said to have been educated in England, was familiarly received by Telford on all occasions; and no doubt the Russian improvements on the coasts of the Black Sea (over which that nobleman now presides) profit by his English recollections. The Emperor of Russia was not inattentive to the unpurchased services of Telford, and sent him a brilliant diamond ring, with an appropriate inscription. [Appendix (W.)] It has already been said, that Telford was honoured by a Swedish order of knighthood; at home he became Fellow of the Royal Society of Edinburgh in the year 1803; of London, in 1827. M. Dupin obtained from Telford, and acknowledges in fit terms, the unreserved communication of all English improvements in civil engineering; and foreigners, distinguished by science and literature, who thenceforth visited England, resorted regularly to Mr. Telford,—Russians, Swedes, Germans, French and Italians. The magnanimity of communication without reserve, he

thought befitted the character of England as well as his own; and he imparted as much knowledge on all occasions as he deemed the applicant was capable of receiving with advantage.

In the more familiar intercourse of life, Telford was equally amiable; and nothing could be more delightful, in accompanying his professional journeys, than to find him received at every inn which he had previously frequented as a family guest, uniformly welcomed by the master, the mistress and the upper servants of the household. In conclusion of the subject of Mr. Telford's character, it is essential to insert a copy of his last Will [Appendix (X.)]; and what cannot but be felt as of much practical value to civil engineers, the contents of a small pocket-book, which he always carried with him for reference to numbers and computations not so well retained in the unassisted memory. [Appendix (Y. 1.)] To this are now added tables of Money and of Measures, useful especially to foreigners, and which will not be deemed unappropriate in a volume which records the expense and the dimensions of many striking monuments of national improvement. To these tables are added a few general observations on Weights and Measures, and arithmetical Notation, corrective of popular error, or opening views of practical utility.

J. R.

CONTENTS OF APPENDIX.

CONTENTS OF APPENDIX.

CONTENTS OF APPENDIX.

A P P E N D I X.

Appendix (A.)

DESCRIPTION of Roman Baths discovered, in the year 1788, at Wroxeter, the ancient Uriconium or Viriconium. Inclosed in a letter from the Rev. Mr. Leighton, of Shrewsbury, to Mr. Gough.

IN the month of June 1788, one Clayton, a farmer, at Wroxeter, having occasion for some stone to rebuild a smith's shop lately burnt down, and knowing by the dryness of the ground that there were ruins at no great depth beneath the surface of a field near his house, began to dig, and soon came to the floor marked I, and the small bath K, in the annexed plan. Application was made to William Pulteney, Esq., the proprietor of the soil, for leave to open the ground farther, which was readily granted. Coins both of the Upper and Lower Empire, bones of animals (some of which were burnt), fragments of earthen vessels of various sizes, shapes and manufactures, some of them black, and resembling Mr. Wedgewood's imitation of the Etruscan vase, and (as Mr. Telford, the architect, informed me) pieces of glass, were found in various places; and the whole ground was full of charred substances in different strata, with layers of earth between them, which seems to indicate that the place has suffered more than one conflagration. I procured a ground-plan and sections of the whole building, as far as it is discovered, from Mr. Telford, a very able architect, who at present superintends several public and private works in this town. To these I shall add nothing more than explanations of the letters of reference in the plan, as I conceive that a general idea of the uses of the different apartments may be formed by comparing Mr. Telford's with the plate of the baths at Baden Weiler, and the learned and admirable explanation of it in the Appendix to Governor Pownal's Notices, &c., concerning the Roman Province in Gaul.

The admeasurement and levels having been taken by myself, I can answer for their truth and accuracy. My description of the ruins I hope will be found intelligible.

References to Sectional Diagram; and also to Mr. Telford's Isometrical View, where applicable to it.

The sections are taken where the lines are drawn plain: viz. two from South to North, and two from West to East.

Where there is only one denomination of figures in the plan or section, it means inches; where there are two, they mean English feet and inches.

I. The floor first discovered. [A. *in Mr. Telford's View.*] It is paved with tiles sixteen inches long, twelve inches wide, and an inch and a half thick. The tiles lie on a bed of mortar one foot thick, under which are rubble stones to a considerable depth.

K. [B *in Mr. Telford's View.*] A bath, capable of holding four persons, supposing them to sit on the steps or seats along the south side. Through the north side is a hole near the bottom marked *a* in the section, at the distance of two feet six inches from the west end. The bottom is paved with tiles, and the sides and seats plastered with mortar, consisting of three layers or coats: the first, or that next the stones, is formed of lime, and bruised or pounded brick without sand; the third of the same, but a greater proportion of lime, and a little sand; this is very smooth on the surface, and very hard.

L L [C C *in Mr. Telford's View*] seem to have been hypocausta, having the foundations of pillars, as marked in the plan. Each lower tile is one foot square, and upon them are others eight inches square; they stand upon a floor of mortar, which in some places is depressed (*see* the section on the line A B) as if forced down by some great weight. The pillars stand at two feet distance from each other, from centre to centre, and are disposed in the same regular manner under the walls of these apartments. The tiles expressed in the plan by dotted lines were not in their places; but, as they were found thrown in other parts of the same hypocausta, it is presumed, from the regularity of the rest, that they originally stood where they are drawn.

About W, immediately under the foundation of the wall, were found several pieces of painted stucco, some of which were in stripes of crimson on a yellow ground, some in a decussated chequer of the same colours, others plain red, and others plain blue. There was found in this place a tile two feet square, pierced with many holes, which holes were wide at the lower side, and ended almost in a point at the upper side.

M [D *in Mr. Telford's View*] is a large floor, formed of a thin layer of mortar, upon a thick one of pounded bricks.

N N [E E *in Mr. Telford's View*] appear like single baths. The only objection to this supposition is, that the walls which form them are very irregular within.

O 1. O 2. [F G *in Mr. Telford's View*] are tesselated floors made of pieces of brick, one inch and a quarter square, not disposed in any fancied form, but in a simple chequer: the tesselæ are all red. O 1. is on a level with the paved floor I. O 2. is nine inches above that level.

P [L H *in Mr. Telford's View.*] A large tesselated floor, made of tesselæ of the same size and colour, and disposed in the same manner as those of O 1. O 2. This is on the western side of the wall which bounds the other apartments. It is on the same level with the floor I, but much crushed down.

Q [I *in Mr. Telford's View.*] A large hypocaustum. Its floor is of mortar, upon rubble-stones, very hard, and lying four feet three inches below the level of I. The pillars are not uniform in their shape, size or disposition: some rows consisted of six, some of seven pillars: some pillars were much shorter than others, and the deficiency was made up by tiles or stones laid upon them: some were apparently the fragments of large columns of

a kind of granite, one foot six inches, and one foot two inches in diameter; others were of a red free-stone, ten inches in diameter; the four small square pillars at X [K *in Mr. Telford's View*] were formed of tiles laid one upon another; in the openings *y y* ashes were found.

R [L M *in Mr. Telford's View.*] A small bath in one corner of the hypocaustum, with one seat or step on two of its sides; the whole of the inside is well plastered with the same sort of mortar as the bath K. This bath stands upon pillars of tiles, one foot square; the intervals between them are from four to seven inches wide, and one foot seven inches high. These pillars stand on the level of the floor of the hypocaustum. From this bath, in the direction R S [L M *in Mr. Telford's View*], there was found a piece of leaden pipe, not soldered, but hammered together, and the seam or puncture secured by a kind of mortar; and there appears a kind of channel or groove cut in large stones, which falls three inches in 12 feet. But for this circumstance of the pipe, I should conjecture R to have been a steam or vapour bath, rather than a water bath, because the eastern side has no wall; but flues or tunnels were found sticking in a perpendicular position, which exactly filled the interval marked (||) between the bath R, and the wall dividing the apartments I and Q. These flues were of tile, with lateral apertures. I forbear to describe them, because it is already done in T. Lyster's account of the hypocaustum formerly found at Wroxeter, in the Philosophical Transactions, No. 306, page 2226, of which hypocaustum there is a good small model in wood in the library of the schools in this town. Fragments of such flues were found in various parts of the ruin. The bath R seems to have wanted the southern as well as the eastern wall; and both those sides might probably be occupied by flues.

T is a place four feet deep below the level of the floor I. It has a paved bottom, and is formed by large granite stones on the southern and eastern sides; on the north by a large thin red stone set on edge. To the east of this place there appears to be another wall running north and south.

Z Z Z [N N N *in Mr. Telford's View*] are intervals between the walls, of the different breadths marked in the plan, intended probably for the purpose of conveying heat by flues to the different apartments, and some possibly for carrying off the water.

The river Severn lies to the west of these ruins, about a quarter of a mile distant. The ground declines from the ruins toward the south. The nearest spring is, I understand, 200 or 300 yards to the north-east, in a situation something higher than these baths.

There is no hot or warm spring in the neighbourhood.

It should be understood by the reader of the above description, that Mr. Telford's *Isometrical View* represents at once both plan and elevation, by what is commonly called a *bird's eye view*; which, notwithstanding its eminent facility and fidelity of representation (well understood in the middle of the last century), is now much fallen into disuse.

APPENDIX (B.)

SURVEY and REPORT of the COASTS and CENTRAL HIGHLANDS of SCOTLAND; made by the Command of the Right Honourable the Lords Commissioners of His MAJESTY'S Treasury, in the Autumn of 1802: by Thomas Telford, Civil Engineer, Edinburgh, F.R.S.

My Lords,

IN reporting upon the survey I made in Scotland, in obedience to the instructions I had the honour of receiving from your Lordships, dated the 1st of July 1802, I find the business may be most conveniently arranged under the following heads:

I.—What regards rendering the intercourse of the country more perfect, by means of bridges and roads.

II.—Ascertaining various circumstances relative to the Caledonian Canal, especially with regard to the supplies of water on the summit level, and the best communications from this canal to the fishing locks at the back of the Isle of Skye.

III.—The means of promoting the fisheries on the east and west coasts.

IV.—The causes of emigration, and the means of preventing it.

V.—Improving the means of intercourse between Great Britain and the northern parts of Ireland, particularly as to the bridges and roads between Carlisle and Port Patrick, and also the harbour of Port Patrick.

Under each of those heads are comprehended subjects highly deserving the attention of Government; the more they are investigated, the more important they will appear, and the public will become more fully convinced, that the general interests of the British Empire are extensively connected with the several improvements which are mentioned in your Lordships' instructions.

OF BRIDGES AND ROADS.

The obstacles which at present obstruct the communications in the north of Scotland are numerous and well known, not only to the inhabitants, but to every person who has travelled through, or even inquired into the state of the country.

Previous to the year 1742, the roads were merely the tracks of black cattle and horses, intersected by numerous rapid streams, which, being frequently swoln into torrents by heavy rains, rendered them dangerous or impassable. The military roads, which were formed about this time, having been laid out with other views than promoting commerce and industry, are generally in such directions, and so inconveniently steep, as to be nearly unfit for the purposes of civil life; and in those parts where they are tolerably accessible, or where roads have since been formed by the inhabitants, the use of them

is very much circumscribed from the want of bridges over some of the principal rivers.

The general connections of the county may be stated as leading from Edinburgh to the north and north-west counties, by means of one road through the Highlands, and by another along the east coast and south shore of the Murray Firth to the town of Inverness, and from thence through Beanley and Dingwall, to Tain in Ross-shire. From Glasgow and Greenock, the communications by land are through Argyleshire, to the western parts of Inverness and Ross-shire, and to the shores opposite the whole of the Hebrides. There is an important communication from Inverness westward, across the country to Fort Augustus and Fort William, and from Fort Augustus there are just the vestiges remaining of what was once a military road to Bernera, opposite the back of the Isle of Skye.

In considering these lines of roads, it appears most regular to begin on the borders of the improved country, and near to the seats of commerce and industry. In proceeding from Edinburgh northwards, by the east coast and Murray Firth to Inverness, or through the central Highlands to the same place, and from thence to Tain on the Dornoch Firth in Ross-shire, we find the communications intercepted, and learn that accidents frequently happen from the want of a bridge over the river Tay at Dunkeld in Perthshire, another over the river Spey at Fochabers in Banffshire, a third over the river Beanley in Inverness-shire, and a fourth over the river Conon near Dingwall, in Ross-shire. These rivers are large, and at present are all crossed by means of ferry boats.

River Tay.

At Dunkeld the river Tay is deep and broad, and there is reason to expect the foundations will be expensive, the bed of the river at and for a great distance above and below the town being composed of alluvial earth and gravel. The best situation for a bridge is a little way above the lower ferry; at this place there is a strait reach of the river, and in winter the ice is broke by passing over a ford nearly opposite the mouth of the river Bran. This situation will also connect with the improved lines of road which are proposed to be made on each side of the river. It is probable that a flat rubble-stone will be got near the slate quarries, which are within a short distance of the place. Freestone of a durable quality is to be had near Dundee; it may be brought by water-carriage to Perth, and from thence by land to Dunkeld.

Under all these circumstances the expense would be considerable, and taking into account the uncertainty of the foundations, the amount cannot be stated at less than £.15,000.

The two ferries which are now at Dunkeld belong to his Grace the Duke of Athol; he has authorized me to state, that if Government will defray one-half the expense of a bridge, he will advance the other half; that he will give up his interest in the ferries, if in lieu thereof a reasonable toll be put upon the bridge, in order to liquidate the capital

advanced by the Duke, after this has been accomplished, with a small surplus to answer the repairs; the bridge ever after to remain free of toll.

This seems a very reasonable and just mode of defraying the expense; the safety and accommodation would be so great, that no person travelling that road could object paying the same toll for a safe and convenient bridge, which at present is paid for a dangerous and inconvenient ferry boat, especially when there will be a certain prospect of having a bridge free of toll in a few years.

This bridge is of the first importance to the central Highlands; it would accommodate a great district of that country, and at the same time facilitate the communication with the North Highlands.

River Spey.

The river Spey is also rapid and deep, being the drain of a great extent of mountainous country, where there is much rain. It is of course a very dangerous ferry. This ferry is on the great coast road eastward from Inverness and Fort George, through the towns and cultivated country in Murray and Banff shires, from whence it passes through Frazerburgh and Peterhead to Aberdeen.

Another branch of road also strikes off Fochabers on the Spey, and passes by Huntley and Inverary to Aberdeen.

The necessity of having a bridge over the Spey at this place became so urgent, that his Grace the Duke of Gordon began a subscription in the adjacent country, in order to raise a part of the money necessary to defray the expense of a bridge; his Grace set a liberal example, and it has been followed by most of the gentlemen in that part of the country. In consequence of this exertion, a contract has been entered into, and some steps have been taken towards carrying this useful work into execution; but unless Government will grant an aid equal to one-half the expense, the works must still be left unfinished, and unfit for the purposes intended.

The situation fixed upon for this bridge is adjacent to the ferry and town of Fochabers. At this place a rock passes quite through the river, at about from eight to ten feet below the surface of ordinary low water; and, as far as I could learn, it is the only place, unless at a great distance up the country, where the rock passes quite through the river. On these accounts it was judicious to prefer it for the situation of the bridge, and it was fortunate this happened precisely in the line of the present road.

As one-half of the expense will be raised by subscription in the neighbourhood, if Government will defray the other half, I understand it is proposed that the bridge shall be free of toll. The expense cannot be stated at less than £. 12,000.

I have made plans and sections for both those bridges. On account of their being so nearly connected with the seats of the two before-mentioned noblemen, I have introduced more decorations than what are absolutely necessary for common road bridges. This extra expense will not amount to much; but, whatever it is, I propose it shall be defrayed by those noblemen.

I last year produced plans and estimates for the bridges over the rivers Beanley and Conon; I have again examined the proposed situations, and perceive that, on account of the uncertainty of the foundations, and the alteration which must be made in some parts of the beds of the rivers, it will be necessary to take the expenses of each bridge at £. 5,000 instead of £. 4,000.

These two bridges are greatly wanted in order to facilitate the communications with Ross-shire, Sutherland and Caithness; they are equally so for the north-west coast of the main land and the northern parts of the Hebrides; they are the roots from which a great number of branches of roads are to proceed, which are necessary for the improvement of the country, and the extension of the fisheries.

Before entering upon the consideration of the roads to the north of the line of the Caledonian Canal, it is necessary to speak of the communications from Glasgow and Greenock, through Argyleshire to Fort William. From Glasgow there is already a road, which passes through Dumbarton up the west side of Loch Lomond, by the upper ends of Loch Long and Loch Fyne, to Inverary. From Greenock, by crossing the Firth of the Clyde, there is a road which passes up the east side of Gare Loch and Loch Long, and joins the road to Inverary at the top of Loch Long. From Inverary there is one road which passes the upper end of Loch Awe, and another which crosses that loch by a ferry at Port Sonachan; and these roads unite at Bunawe on the banks of Loch Etive From Bunawe the road is already made to Oban, and a branch crosses Loch Etive, and passes along the south side of the Linnhe Loch and Loch Eil to Fort William. Between Bunawe and Fort William there are three ferries over arms of the sea, which, running many miles into the land, cannot well be avoided; in other respects the communication from Glasgow and Greenock, thus far, is tolerably good. The Highland Society, in the excellent Report to which I shall frequently have occasion to refer, and which may be found in the Appendix [L. 1.] have pointed out a new line of road from the north side of the Firth of Clyde, nearly opposite to Greenock, to be carried to the Bay of Strachaur upon Loch Fyne. This would be a very direct line from Greenock to Inverary, but it would be subject to two ferries; and it seems doubtful whether this inconvenience would not overbalance the additional distance round the upper end of the lochs; at least, as there is already a very good communication by this road, it seems most prudent to attend to the other more necessary portions of road before this is undertaken.

From Fort William it will be very advisable to improve and extend the road which passes along the north side of the portion of Loch Eil, which turns from Fort William to the west, and to carry it from thence by the upper end of Loch Shiel, through Arrasaig to Morer, as described in the Report of the Highland Society. This would open a very direct communication from the Clyde to the fishing lochs at the back of Skye, to Skye itself, and to the islands of Egg, Rum, Muck, Barra and South Uist. This would prove of great importance to the fisheries, on account of facilitating intelligence, which is one of the most necessary steps to promote the success of this business.

In the year 1796, Mr. Brown, of Elgin, made a survey and estimate of this road from Fort William to Morer, and stated the expense at £. 6,456. Since that time, I understand

that about £.1,500 has been laid out upon it; so that £.4,000, and perhaps somewhat more, is still required to render it perfect.

With regard to the improvement of the roads which lead from Fort William, east, to Inverness, there is one principle which in future ought never to be lost sight of; which is, to make the new roads as near to the banks of the rivers and lochs as is practicable, at a reasonable expense. If the Caledonian Canal is executed, it is more than probable that many improvements will be pointed out in the course of carrying on that great work, and it would be imprudent to decide rashly in a matter which is so much connected with this national object.

We now come to consider the communications of the countries which lie to the north and west of the track of the Caledonian Canal. From this valley, which runs from Fort William to Inverness, it is of great importance that there should be lines of communication with the Isle of Skye, and the fishing lochs which lie at the back of it. These lines of road are not only necessary for promoting the fisheries, but are urgently called for by the situation of the interior parts of the country, where there are many fertile valleys which hitherto have remained nearly inaccessible. It is incalculable the loss which the public has sustained, and are about to suffer, from the want of roads in this country.

From the bridges of Beanley and Conon, lines of road, from the same important causes, are wanted in several directions to the west coast, and through the whole of the counties of Ross-shire, Sutherland and Caithness. The outlines of those roads are well described in the Report of the Highland Society, and, although there is a diversity of opinion as to the comparative importance of some of them, as well as of those to Skye, yet it is evident that they are all necessary for the welfare of the country.

The empire at large being deeply interested in those improvements as it regards promoting the fisheries, and increasing the revenue and population of the kingdom, justifies Government in granting aid towards making roads and bridges in a country which must otherwise remain, perhaps for ages to come, thus imperfectly connected; yet as the landowners in those extensive districts through which the roads would pass, and indeed the whole of the adjoining districts of country, would enjoy improved cultivation and pasturage, increased incomes, and all the blessings which are to be derived from a facility of intercourse, it is certainly just that they should contribute a share with Government in the expense of acquiring those advantages. They might be enabled to do this without inconvenience to the present possessors, by being empowered by an Act of Parliament to sell land, or borrow money upon the land, to the amount of their proportion of the expense to be incurred by the roads and bridges. This is reasonable, because the money so raised would be applied to improve the remainder of the entailed estate, which would be enhanced in value, though somewhat diminished in extent.

The expense of the lines of road which were surveyed and estimated by Mr. Brown, comprehending the whole of the before-mentioned counties, and nearly 1,000 miles in length, did not amount to £.150,000. If, therefore, we admit an equal quantity of lines of road to be undertaken and completed in the course of three years, it would require an

annual supply of £. 50,000, and supposing this to be raised in equal moieties by Government and the land-owners, it would be £. 25,000 each; but as it is not likely the whole could be brought so immediately into operation, it may with more probability be expected that six years would be taken up in executing all the lines, which would reduce the annual supply to £. 25,000, or £. 12,500 from each party. But this is exclusive of the four great bridges, the total expense of which is reckoned at £. 37,000. If they were undertaken by proper persons, they might be executed in three years, which would require an annual supply of £. 12,333. 6*s.* 8*d.*; and if Government were to grant—

One-half, would be - - - - - -	£. 6,166	13	4	annually.
To which add the former - - - -	12,500	–	–	
	£. 18,666	13	4	

Speaking therefore generally, if Government were disposed to encourage these plans of improvement, and would agree to advance £. 20,000 in each of the first three years, and £. 12,000 in each of the last three years, it would then remain with the land-owners of the districts of country through which the lines were to be carried to come forward with their surveys and estimates, and subscriptions to one-half the amount of the expense, proving at the same time, to the satisfaction of Government, that the proposed lines would be of public as well as of private utility. It would be necessary also to provide that the works should be substantially executed, and that the land-owners or others interested should always lay out a certain sum before Government advanced an equal moiety.

Means should be provided for the maintenance of the roads and bridges after they have been completed; and for this purpose there should either be a fund reserved, or a small toll laid on, to go in aid of the statute labour of the country. A very important consideration also is the erecting and maintaining proper inns upon the roads.

Several of the houses which were built by Government upon the military roads are striking instances of the necessity there is of giving the people who are to keep the inns something else to depend upon besides what arises from supplying travellers; there should be some land attached to the house, at a rent to be settled by reference. I am not prepared to say what the quantity should be, or of what particular description; it is at present sufficient to point out the principle.

Upon the whole, as far as regards the bridges and roads, I can have no hesitation in stating that they are of the greatest moment for promoting the improvement of the country, and for perfecting the connections with the fishing lochs and the Hebrides; and I shall hereafter endeavour to explain my reasons for thinking that some share of the emigrations is to be attributed to the want of proper communications.

NAVAL STATIONS.

Before entering upon the subject of the Caledonian Canal, it will be proper to observe that I again examined the Bay of Cromarty, and have procured some more information respecting it and the Murray Firth.

Mr. Henderson, the resident custom-house officer, a man of respectability, has, at my desire, ascertained the depth of water in the wells, and also what quantity flows from a spring about half a mile from the town. From his letter it appears that at the depth of twenty feet from the surface of the plain upon which the town stands, there are four feet of water in their wells. When at Cromarty, I learned that at high springs this water is brackish; but it is generally used for washing and other domestic purposes. At the distance of about half a mile from the town there is a fine spring, which was discovered by the late Mr. Ross during his ineffectual attempt to find coal: from this circumstance it is called the coal-well. This spring produces, on an average, upwards of twenty hogs-heads of water in an hour; this water might be collected into a reservoir at a small expense; from this reservoir it might be brought to the shore, which is a short distance, in pipes, and, by means of hose, run into casks in a ship's boat; to protect the boats, a small pier might be formed at this place.

Captain Duff.

Captain Duff, of the Royal Navy, who is well acquainted with the country, and has navigated the Murray Firth in a frigate, has been so obliging as to resolve some queries which I took the liberty of transmitting to him through his brother-in-law, Colonel Dirom. Captain Duff confirms the general report of the excellence of the Bay of Cromarty, and the entrance to it; his opinion respecting the navigation of the Murray Firth is quite as favourable as I had been led to advance in my last Report. From what he states, it appears that, even with a contrary wind, a ship of war could clear the headlands in forty-eight hours from the time of leaving the Bay of Cromarty. From this account persons conversant in naval affairs will be able to judge how far this bay would be suitable for a squadron destined to watch the mouth of the Baltic, and protect the coast. It would be singularly well situated for convoys to vessels coming from the westward through the Caledonian Canal, and when returning with the same trade; after seeing the merchant ships pass Fort George, the ships of war would be close in with their own harbour.

Aberdeen.

As an aid to this station, the harbour of Aberdeen might be made to receive frigates; this harbour is not embayed, and frigates might sail from it at all times. In my last report I stated the expense which would attend improving this harbour, and I distinguished what extra expense would be required to render it capable of receiving frigates, which appeared to be £. 33,700.

The magistrates of the town, by whose spirited exertions several valuable improvements have already been effected, have authorized me to say, that they are ready to co-operate with Government as far as their circumstances will admit. If frigates were stationed at Aberdeen, and large ships at Cromarty, a naval protection would be immediately obtained in that quarter at a very moderate expense, and experience would point out what future improvements were necessary upon this coast.

From Aberdeen, Peterhead and Frazerburgh, a communication might be kept up with Cromarty by means of signals or a telegraph, or by land expresses to Nairn, where the

Firth is only three leagues over; or a fast sailing vessel would soon run, with an easterly wind, from Frazerburgh to Cromarty.

If Cromarty Bay was made a roadstead, there would be wanted a storehouse and some other conveniences, which may be on a small scale, until the merits of the place have been fully proved; allow an expense here of £. 5,000.

THE CALEDONIAN CANAL.

I passed along the whole line of this canal, that is, from Inverness on the east to Fort William on the west coast. I took much pains to examine into the nature of the navigation of the lochs, their soundings and anchoring places. For this purpose I applied chiefly to Mr. Gwynn, who has commanded the Loch Ness galley in Government service 36 years; from him I obtained a very full and satisfactory account of Loch Ness; he also took the soundings of Loch Oich and a part of Loch Lochy for me.

From him I learnt that Loch Ness is 22 miles in length, and from one to two and a half miles in breadth, that its extreme depth is 135 fathoms, and generally from 15 to 20 very near the shores; that there are six anchoring places on the north and four on the south side, and that at each end of the loch there is good anchorage in from three to five, eight and ten fathom water:

That a vessel passing from the west to the east end before a westerly wind, or in a contrary direction before an easterly wind, has nothing to do but run before the wind the whole way, which she would do in from three to five hours, and with contrary winds in moderate weather she would work it in from 24 to 36 hours:

That the easterly winds generally prevail from March till the end of September, when the westerly winds set in and continue for the rest of the year.

The soundings he took in Loch Lochy are from seven to sixty-eight fathoms, with bold shores and good anchorage.

In Loch Quoich, which is a short loch on the summit level, there are some shallow parts, but they may be made sufficiently deep.

I next proceeded to examine the supplies of water which are on the summit level, and for this purpose I passed up the valley of Glengarey to Loch Hourn, at the back of Skye. In this valley I found Loch Garry, which appears to be upwards of five miles in length, and from half a mile to one mile in breadth; towards the head of the valley is Loch Quoich, which appears to be upwards of eight miles in length, and from one to two miles in breadth; these natural reservoirs, placed in an extensive valley and a rainy country, form an abundant provision for every purpose to which water can be applied in the course of the canal.

Having ascertained these points, I passed by a very rocky and precipitous track down to the head of Loch Hourn; from Loch Hourn I travelled by a track scarcely less rugged,

to the top of Glen Elg, and over the steep mountain of Raatachan to the top of Loch Duich; from thence I travelled along the vestiges of a military road, up Glen Shiel, down a part of Glen Morrison, and over a rugged mountain to Fort Augustus. In Glen Morrison and Glen Garry it is possible to make roads, if judiciously laid out, upon an easy ascent; but the idea of water conveyance through them between the Caledonian Canal and the fishing lochs is altogether unadvisable.

My next object was to examine the country which lies between the top of Loch Eil and Loch Shiel, in order to find whether a water conveyance could be made at a moderate expense from Loch Eil through Loch Shiel, and so into the fishing grounds to the south of Skye, without passing down the Linnhe Loch, up the sound of Mull, and round the point of Ardnamurchan. I carried a level across the neck of land which separates Loch Eil from Loch Shiel; the distance is about three miles. I found the summit of the land 43 feet above high water in Loch Shiel, and 35 feet 5 inches above the level of the fresh water in Loch Shiel. In order to form a canal, as there is no water to be got on this summit, the ground must be cut down to 12 feet below the level of the water in Loch Shiel, which would make 47 feet 5 inches of cutting, and this depth of cutting would be continued for nearly a mile; I also suspect that in this distance rock would be met with. I am, therefore, sorry to say, I cannot advise the work being undertaken before the nature of the ground has been fully proved, and the whole of Loch Shiel has been examined with great care; and as this passage cannot be useful, unless the Caledonian Canal be made and navigated from the east, if that event should take place, there will be plenty of time to re-examine this point with care; at present it ought, in my opinion, to be postponed.

Having investigated all the points which fell under my observation as a civil engineer, I became extremely desirous of having the opinion of experienced and well-informed mercantile and seafaring people, with regard to the present navigation by the Pentland Firth and the Orkneys, and the proposed inland navigation by the Caledonian Canal; with the view of procuring the best possible information on this subject, I applied to Leith, Aberdeen and Peterhead, on the east coast, and to Greenock, Dublin, Liverpool and Bristol, on the west.

In the Appendix to this Report I have inserted the queries and answers, by which it may be seen that there is only one opinion as to the dangers and inconveniences of the present navigation, and the advantages which may be expected from the proposed inland navigation, if united with a naval station in the Murray Firth, or on the adjacent coast of Scotland.

This sanction of experienced people, who are all deeply interested in commercial concerns, will, I trust, satisfy your Lordships that it has not been upon unsubstantial grounds that I have ventured to recommend this great national object.

My estimate of the expense of forming this navigation is nearly £. 350,000, and the time required to complete it would probably be about seven years; this division would require an annual supply of £. 50,000.

Upwards of 30 vessels have been wrecked on the coast of Caithness, in the memory of Alexander Miller, of Staxigo.

THE FISHERIES.

In what regards the Fisheries, I beg leave to quote a passage from my last year's Report: "I believe it is generally admitted, that in the improvement of a country the interference of Government should extend only to the removing obstacles, and affording conveniences, which are of a nature not easily to be surmounted by individuals, or any body of men who can be brought to act together; and where it is evident that, by removing those obstacles and affording these conveniences, the exertions of individuals will be greatly facilitated, so as to promote the general good of the empire."

The objects connected with the Fisheries, which seem to come under the foregoing description, are, 1st, the want of a ready communication by water between the east and west coasts; 2d, the want of communications by land from the low countries and the east coast, with the shores and fishing lochs of the west coast; 3dly, the inconveniences arising from the operation of the Salt Laws; and 4thly, the want of a harbour in Caithness.

The first and second of those objects have already been fully discussed under the heads of the Caledonian Canal, and the proposed bridges and roads. The third has been so often and thoroughly investigated, that I shall only in this place take the liberty of mentioning, that all the information I have received tends to confirm the justice of the complaints against the laws now in force which regard salt.

As to the fourth object, the harbour of Wick, in Caithness, which I examined, estimated and reported upon last year, will remove the just complaints of want of protection on the north-east coast.

EMIGRATION.

That emigrations have already taken place from various parts of the Highlands, is a fact upon which there does not remain room to doubt; from the best information I have been able to procure, about three thousand persons went away in the course of last year, and, if I am rightly informed, three times that number are preparing to leave the country in the present year.

I shall not encroach upon your Lordships' time by investigating all the remote or unimportant collateral causes of emigration, but shall proceed to that which I consider to be the most powerful in its present operation; and that is, converting large districts of the country into extensive sheepwalks. This not only requires much fewer people to manage the same track of country, but in general an entirely new people, who have been accustomed to this mode of life, are brought from the southern parts of Scotland.

The difference of rents to the landlords between sheep and black cattle is, I understand, at least three to one, and yet on account of the extraordinary rise in the prices of sheep and wool, the sheep farmers have of late years been acquiring wealth. As the introducing sheep farms over countries heretofore stocked with black cattle creates an extensive

demand for the young sheep from the established farms, it is possible that the high prices may continue until a considerable portion of the country is fully stocked; after this takes place, the quantities of sheep produced will bear a very great proportion to the demand, and then it is possible the prices may fall below the average value; in this case it is probable the farms will be subdivided, and a proportion of black cattle and cultivation be introduced in the lower grounds in the valleys, while the upper parts of the hills continue to be pastured with sheep. This I consider as the most improved state of Highland farming, and is consistent with a very considerable population; a beautiful instance of this is to be seen along the north side of Loch Tay. But improved communications, by means of roads and bridges, are necessary for this state of society; and for this reason I have said, that if these conveniences had been sooner introduced into the Highlands, it is possible this emigration might not have taken place, at least to the present extent.

The very high price of black cattle has also facilitated the means of emigration, as it has furnished the old farmers with a portion of capital which enables them to transport their families beyond the Atlantic.

In some few cases a greater population than the land can support in any shape has been the cause of emigrations; such was the island of Tiree.

Some have, no doubt, been deluded by accounts sent back from others gone before them; and many deceived by artful persons, who hesitate not to sacrifice these poor ignorant people to selfish ends.

A very principal reason must also be, that the people, when turned out of their black-cattle farms to make way for the sheep farmers, see no mode of employment whereby they can earn a subsistence in their own country, and sooner than seek it in the Lowlands of Scotland, or in England, they will believe what is told them may be done in the farming line in America.

What I have here mentioned appear to me to be the immediate causes of the present emigrations from the north-western parts of Scotland. To point out the means of preventing emigrations in future is a part of my duty, upon which I enter with no small degree of hesitation. As the evil at present seems to arise chiefly from the conduct of land-owners, in changing the economy of their estates, it may be questioned whether Government can with justice interfere, or whether any essential benefits are likely to arise from this interference.

In one point of view it may be stated, that, taking the mountainous parts of Scotland as a district of the British Empire, it is the interest of the empire that this district be made to produce as much human food as it is capable of doing at the least possible expense; that this may be done by stocking it chiefly with sheep; that it is the interest of the empire the food so produced should not be consumed by persons residing amongst the mountains totally unemployed, but rather in some other parts of the country, where their labour can be made productive, either in the business of agriculture, fisheries or manufactures; and that by suffering every person to pursue what appears to them to be their own interest, that, although some temporary inconveniences may arise, yet, upon

the whole, that matters will in the end adjust themselves into the forms most suitable for the place.

In another point of view it may be stated, that it is a great hardship, if not a great injustice, that the inhabitants of an extensive district should all at once be driven from their native country to make way for sheep farming, which is likely to be carried to an imprudent extent; that, in a few years, this excess will be evident; that before it is discovered, the country will be depopulated, and that race of people which has of late years maintained so honourable a share in the operations of our armies and navies will then be no more; that in a case where such a numerous body of the people are deeply interested, it is the duty of Government to consider it as an extraordinary case, and one of those occasions which justifies them in departing a little from the maxims of general policy; that for this purpose regulations should be made to prevent land-owners from lessening the population upon their estates below a given proportion, and that some regulation of this sort would in the end be in favour of the land-owners, as it would preserve the population best suited to the most approved mode of Highland farming, such as is practised at Breadalbane, and to the establishment of fishing villages, on the principle laid down and practised so successfully by Mr. Hugh Stevenson, of Oban, at Arnisdale, on Loch Hourn.

In whatever light the foregoing statements may be viewed, there is another on which there can, I think, be no difference of opinion. This is, that if there are any public works to be executed, which, when completed, will prove generally beneficial to the country, it is advisable these works should be undertaken at the present time. This would furnish employment for the industrious and valuable part of the people in their own country, they would by this means be accustomed to labour, they would acquire some capital, and the foundations would be laid for future employments. If, as I have been credibly informed, the inhabitants are strongly attached to their native country, they would greedily embrace this opportunity of being enabled to remain in it, with the prospect of bettering their condition, because, before the works were completed, it must be evident to every one that the whole face of the country would be changed.

The Caledonian Canal, and the bridges and roads before mentioned, are of the description here alluded to; they will not only furnish present employment, but promise to accomplish all the leading objects which can reasonably be looked forward to for the improvement and future welfare of the country, whether we regard its agriculture, fisheries or manufactures.

London, 15th March 1803. *Thos. Telford.*

APPENDIX (C.)

CALEDONIAN CANAL.

REPORT from the COMMITTEE on Mr. *Telford's* SURVEY of the HIGHLANDS of SCOTLAND.—14th June 1803.

THE Committee having considered, in their two former Reports, the nature and extent of the emigrations from the Western and Northern Highlands of Scotland, and the necessity of making roads and bridges, to open communications with the fishing lochs and stations, and with districts of country which are at present nearly inaccessible, have proceeded to the consideration of that part of Mr. Telford's survey which relates to forming an inland navigation from the eastern to the western sea, by Inverness and Fort William; and have now received all the evidence they think necessary to enable them to form an opinion on this subject.

Your Committee, being aware of the importance of this great national object, have, with much care, examined sundry experienced and respectable shipmasters, with regard to the present navigation by the Pentland Firth, Cape Wrath and the Minch, to the Irish Channel; from the testimony of several persons long experienced in this navigation, it appears to your Committee, that this navigation, so far as regards the commercial intercourse between the western and eastern coasts of Great Britain, or between a considerable part of Ireland and the eastern coasts of Great Britain, or between a considerable part of Ireland and the northern parts of Europe, or between the western coast of Great Britain and the same countries, by the Pentland Firth, is not only very circuitous, but during the autumn and winter, especially in long nights, on account of the thickness of the weather, the violence of the waves, the rapidity and diversity of the tides, is peculiarly difficult and dangerous. It appears, however, to your Committee, that some difference of opinion prevails as to the extent of that danger, for Captains Huddart and Fraser, whose authority must in all cases have great weight, seem not to think it very considerable. But the contrary opinion is entertained by all those who have had personal experience of that navigation, and is supported by the acknowledged facts of frequent and distressing losses of property to a large amount, and of many valuable lives.

Your Committee having also examined, with much attention, sundry experienced mariners and civil engineers, as well as Captain Gwynn, the commander of the Government galley on Loch Ness, a man of thirty-seven years experience in that service, as to the practicability of forming the canal, and navigating both that and all the locks between Inverness and Fort William with ships of burthen, and likewise as to the difference of time and safety in passing through this navigation, when compared with that by the Pentland Firth, Cape Wrath and the Minch; your Committee find, that the navigation of the Murray Firth from Buchanness to Fort George is very safe, has favourable tides, a spacious and commodious harbour in the bay of Cromarty, on the north-west side of the Murray

Firth, and a tolerable good one at Brough Head on the south side thereof:—That, between Fort George and Inverness, there is a loch of safe navigation and good anchorage; from Inverness to the north-east end of Loch Ness, a distance of about seven miles, that the ground is favourable for a canal, and that Loch Ness, which is about 22 miles in length, and from one to two and a half in breadth, is of great depth of water, and quite free in its channel from rocks or impediments to the navigation; that there are six anchoring places on the north, and three on the south side thereof, besides excellent anchoring ground at each end; that it never freezes, and though subject to occasional gusts of wind, yet they are not sufficiently violent to be dangerous, except from the end of November to the beginning of February: from Loch Ness to Loch Oich, a distance of about five miles, the ground is very favourable for making a canal. Loch Oich, which is on the summit level between the east and west seas, is only about 100 feet above the level of high-water mark; it is about four miles in length, and receives the waters from Loch Garry, Loch Quoich, and all the valley of Glen Garry and Glen Quoich, affording a supply of water beyond every possible demand. Loch Oich is narrow, being only from one quarter to three quarters of a mile in breadth, and is calculated to be navigated by means of tracking, in the manner of a canal.—From Loch Oich there is only a distance of one mile and a half of ground to the north-east end of Loch Lochy; and this ground is also favourable for making a canal.—The north-east end of Loch Lochy is peculiarly well formed as an entrance basin, being separated from the body of the loch by a narrow channel; there is a sufficient depth of water and good anchorage.—Loch Lochy is about ten miles and a half long, and from one and a half to two miles in breadth; it is quite clear of rocks, and has good anchorage at each end, and also good anchorage near to the middle of the south side at Letter Findlay.—The waters of Loch Arkeg fall into the north side.—The surface of Loch Lochy is about 20 feet below that of Loch Oich, and about 80 feet above high-water mark at Fort William. From the south-west end of Loch Lochy to the shore of Loch Eil, which is an arm of the western sea, the distance is about seven miles; a road might readily be formed along the south side of Loch Lochy, and vessels might be tracked in calms or against light breezes. Between Loch Lochy and Loch Eil the ground is more rugged than in the other districts, but, consisting of small risings, the tops of which may be thrown into the valleys, is not unfavourable for a canal, and there is no appearance of rock, any where upon the surface, in the line of the proposed navigation. The entrance into the sea at Loch Eil is at a place where there is good shelter and anchorage for any number of vessels of burthen. From Fort William down the Linnhe Loch, until it becomes part of the main sea, between Oban and the south end of the Isle of Mull, the navigation is clear, and the tides are favourable; in the course of this loch there is shelter and anchorage, and within a little of the extremity of the Linnhe loch are the excellent harbours of Oban and Tobermory.—From Oban the navigation lies within the islands, passes near the mouth of Loch Crinan to the Irish Channel, or through the Crinan Canal to the Firth of Clyde, so that from the entrance of the Murray Firth on the east, to the Mull of Cantyre on the west, there is no risk from storms or an enemy.'

From the evidence of three respectable shipmasters, who have been many years employed in navigating those seas, it appears that, from Buchanness on the eastern extremity of the Murray Firth to the entrance of the Irish Channel, the average passage

at present is above a fortnight; it has frequently been from two to three months. It has been performed in five days; but for so short a passage, not only very fair winds are necessary, but they must change three times.

From Buchanness to the entrance of the Irish Channel, by the inland navigation, with a moderate and fair wind, the passage might be readily and regularly made in five days; with a moderate but contrary wind, in nine days; and with any contrary wind, when sail could be carried, in twelve days; the great superiority therefore of the proposed canal to the present navigation is evident, in expedition as well as safety.

There have been submitted to the consideration of your Committee several communications from well-informed persons, of the ports of Dublin, Liverpool, Greenock, Leith, Aberdeen and Peterhead, which all agree with respect to the dangers attending the present navigation by the Pentland Firth and Cape Wrath; and with respect to the advantages before stated, which must arise, from the proposed navigation, to commerce and the fisheries.

Your Committee are therefore deeply impressed with the immediate necessity of employing the people of the country in the execution of this great national work; which will excite a spirit and introduce habits of industry, and will most probably check the present rage for emigration, and prevent its future progress.

Your Committee are equally convinced of the practicability, as of the importance, of this work. The strata under ground along the line of the canal have not yet been proved, by sinking pits or boring; but from the general appearance of the soil near the surface, there is no reason to suppose that there is any rock near the surface of the ground in the line of the canal; and from estimates, which have been made under this supposition, it appears to the Committee, as far as they can depend upon Mr. Telford's knowledge of local circumstances, stated in his Report, that, exclusively of the value of land, which, except near Inverness, is in general of inferior quality, the execution of the works, in a very plain though substantial manner, with the materials to be found in the country, and with the advantage to be derived from the superabundant supplies of water on the summit level, which will enable the engineer to introduce a new and very economical mode of forming the locks, that the whole expense of a canal, to contain twenty feet depth, would not exceed three hundred and fifty thousand pounds. It appears, however, to the Committee, from Mr. Jessop's mode of calculation, that his estimate would amount to four hundred and seventy-eight thousand five hundred pounds, but he estimates each lock at ten thousand pounds, whereas Mr. Telford calculates the twenty-five locks at five instead of ten thousand pounds each; which excess of estimate beyond Mr. Telford's is therefore accounted for within the sum of three thousand two hundred pounds, by the difference of the expense of twenty-five locks.—Mr. Rennie supposes that the proposed canal would cost from six to seven hundred thousand pounds; but your Committee beg leave to observe, that neither Mr. Jessop nor Mr. Rennie are acquainted, from their personal observations, with any local circumstances, they not having ever made a survey, nor having ever been upon the line of the canal; but form their judgment from their experience of other works.

Your Committee, from a full consideration of all the evidence laid before them, and annexed to this Report by way of Appendix, submit to the House their opinion, That the execution of the inland navigation, proposed in Mr. Telford's survey, under all due regulations for the economical expenditure of such monies as may be employed in this great work, will be a measure highly conducive to the prosperity and happiness of that part of Scotland in which it is situated, and of great importance to the general interests of the whole United Kingdom.

NAMES of COMMISSIONERS for the CALEDONIAN CANAL, appointed by Act of Parliament, 27th July 1803.

The Right honourable the Speaker of the House of Commons for the time being,—(Charles Abbot, afterwards Lord Colchester.)
The Chancellor of the Exchequer for the time being,—(Mr. Addington, now Lord Sidmouth.)
The Master of the Rolls for the time being,—(Sir William Grant.)
Lord Castlereagh,—(afterwards Marquis Londonderry.)
Lord Binning,—(afterwards Earl of Haddington.)
Lord Dunlo,—(afterwards Earl of Clancarty.)
The Honourable Robert Dundas,—(now Lord Viscount Melville.)
Sir William Pulteney, } Baronets.
Sir Robert Buxton, }
Nicholas Vansittart,—(now Lord Bexley.)
Charles Grant, } Esquires.
Isaac Hawkins Browne, }

John Rickman, Secretary.
Thomas Telford, Engineer.
James Hope, Law Agent at Edinburgh.

APPENDIX (D.)

CONSTRUCTION of the SEA-LOCK at CORPACH.

AT Corpach, the western end of the canal, it was found necessary to connect the canal with the tideway on the north-west side of a rock, situated about 100 yards below high-water mark; this rock is covered at three-quarters flood, and the lock had to be advanced so far into the sea as to admit the sill to be laid upon rock, when there should be 21 feet of water upon it at high water of neap tides. For this purpose, water-tight mounds, faced with rubble-stone, were carried from the shore beyond the extremity of the lock-pit. Between these mounds a wooden cofferdam was constructed.

The clearing away the gravel, sand and mud, the fixing the main piles, and placing the wooden frames in their proper places, were operations of considerable difficulty, and merit to be recorded for the benefit of engineers who may be engaged upon similar works.

By boring with augers, it was found that a proper depth might be obtained about 21 yards below low-water line of spring tides, and this space was enclosed with a cofferdam in the spring and summer of 1807. From the earthen bank, to near the end of the timber-work of the cofferdam, the first leading frame was begun in August, and put together on the beach, near high-water mark; this was done by fishing together, end to end, two beams 13 inches square, by pieces 20 feet long, 13 inches broad and 6 inches thick, laid on opposite sides of the beams, across the joinings, and fastened by four screw-bolts, which passed through the whole; the length of the beams (as fished together) was 95 feet. In order to join the sides of the frames, from the ends of the last-mentioned beams, two others, each 63 feet, were laid with an inclination to each other, which left their ends 65 feet apart; they were fastened to the ends of the long beams by half chucking or gaining,* and passing two screw-bolts through each corner. There was a beam, 38 feet, laid across each angle, and fastened down to the front and side leading beams by screw-bolts. At the height of the springs, this first leading beam was floated off, and at low water adjusted to its precise situation, and sunk to the bottom by means of a number of large stones; a considerable degree of attention was bestowed in adjusting the first frame, because upon this depended having the cofferdam and the lock in a proper direction. On the upper side of this leading beam, previous to its being sunk, there were three mortices cut on each side, and three in the front, which were to receive the tenons made in the lower end of the standards, which were placed upright therein, and cut off at the level of one foot below high-water neap tides, in order to receive the middle leading frame. This last-mentioned frame, after it had been made on the shore, was floated off to its place, but after two or three fruitless attempts to rest it on the top of the standards, as the tide left it, being found impracticable in so strong a tide, it was abandoned. This led to the placing a pile-engine upon the deck of a sloop, and driving three piles along the front and two at each side, all close to the outer side of the lower leading frame; long brackets were nailed to the inside of these piles, level with the tops of the upright standards; the frame was then again floated into its place, when it rested on the brackets and standards, and was screwed down in its place. Upon this second leading frame were also upright standards fixed in mortices, and cut off at high water of a spring tide. The upper leading frame was floated off, and placed upon the standards; for doing this, advantage was taken of one of the high spring tides in the beginning of October; this frame was likewise bolted to the piles; a temporary scaffold was made above the top of the frame, by laying large beams across, and driving piles within the space to support them. The whole was now loaded with stones; a large pile-engine was placed on the scaffold, and a number of piles on the outside of these frames, at 15 and 20 feet apart; they were bolted to the uppermost frame, to keep the whole steady during the winter storms.

* Sometimes called by the workmen cogging or corking.

In March 1808, the work was recommenced by putting down the main framing piles, and fixing to the rock by means of iron dowells. For this operation there was first constructed a cylinder of three-inch plank, 22 inches diameter on the inside, and eight feet long; the joints were made perfectly correct, and dowelled together, and it was hooped with flat bars of iron; the lower end was shod with a circular iron shoe on the edge of

the timber. To prevent its being damaged by storms, while driving down to the rock near the upper end, and on the opposite end of the cylinder, two strong eyes were fixed, by means of strong iron clamps, which embraced the cylinder, and were riveted to the sides. This was done to receive a strong iron chain to lift up the cylinder, and also for drawing it out of the sand and mud after the pile was fixed. At low water this cylinder was placed in the situation where the centre of the main pile was to lie; at this place there were three feet at low water, and eight feet and a half of silt and gravel on the rock. The cylinders being lifted up by the ropes fixed on the top of the pile-engine frame, it was set perpendicular on the surface of the sand, and close to the inside of the lower leading frame; on the top of it was placed a block of ash timber two feet high; on the lower end of this, six inches were turned, to fit exactly the inside of the cylinder, to prevent the block from shifting, and also the cylinder from crushing during the driving. This block was strongly hooped with iron, as was also a pile 12 inches square, that stood on the top of it, and reached as much the top of the upper scaffold as the cylinder had to sink in the mud. The whole was now lashed in such a manner as to keep them perpendicular, and at the same time to allow them to sink; the driving was then commenced with a pile-engine 30 feet high, and a ram, 1,008 pounds weight. At first, the cylinder went freely, but by the time it had sunk three feet and a half, it went so stiffly, that it was found advisable to begin emptying the matter out of the inside. For this purpose, a peculiar instrument was made, forming a quadrant of the same circle as the inside of the cylinder,—the circular side, and one of the strait sides of the quadrant (six inches up) being made of thin rolled iron, riveted to the ribs, which were fastened to the corners of the quadrant, from which proceeded an upright shaft,—the other strait side being left open; upon the bottom of it, four flat teeth, two inches and a half long, were fixed with an inclination downwards, so that as the auger turned round, these teeth loosened the sand, and prepared it to enter easily into the body of the auger; to preserve it steady while turning, there was fastened to the lower side of the corner of the quadrant, which is the centre of the circle, a pivot six inches long, which passed into the sand, and served as a centre for the auger to turn upon; immediately above the pivot stood the upright shaft, which for ten feet was of iron one inch and a half square, and for twelve feet more, a piece of timber four inches square; upon these, two cross handles were placed to turn it with, and they were to slide up and down, as the auger rose and fell. At five feet below the upper scaffold, where the engine stood, a temporary scaffold was erected, on the top of the second leading beam, where four men might stand and work the auger; in this lower scaffold was a round hole through which the wooden shaft of the auger passed and was kept steady; when at work, two complete turns filled it; it was then lifted up above the water by a purchase from the top of the pile-engine, and the sand was cleaned out by means of a small shovel. The operations of boring and cleaning out were repeated alternately, till the lower end of the cylinder rested on the rock; there was then a frame which fitted to the end of the cylinder, introduced into its upper end, and sunk to the bottom by means of two half-hundred weights. Down a square hole in the middle of this frame was introduced a pipe, four inches square at the top, and tapered to three inches at the bottom; this was driven down to the rock through the small quantity which the auger could not clear. The sand which was enclosed in the pipe was

cleared off the rock by a cylindrical iron tube three inches diameter on the outside, and three feet long, which had a valve fixed within two inches of the bottom, and rested on a small ring fastened to the inside of the tube; on the top of the tube was a screw, by which it was fastened to a set of boring rods. It was then passed down to the bottom of the square wooden pipe, and by working by short and quick strokes, the before-mentioned sand and gravel worked above the valve by the agitation of the water. The tube was then taken out and emptied, and this operation was repeated until the rock within the square tube was perfectly clean. It was found absolutely necessary to clear away this sand, otherwise it entirely prevented the jumper from turning on the rock.

A jumper was then passed through the square directing pipe, and worked by a lever on the upper scaffold, until a hole 2½ inches diameter and 20 inches deep was bored into the rock, to receive the iron dowell 2 inches square; this dowell was fixed in its place by fastening it into a square socket, made in the end of a 1½ inch square iron bar, by a small cord to prevent its falling out of the socket, while lowering the square directing pipe to the rock; it was driven into the hole in the rock by striking with a large hammer on the head of the bar; when it had been driven 18 inches into the hole, the timber was lifted up by a sudden jerk, which broke the cord, and left the dowell in its intended situation; the frame and square directing pipe were then lifted out of the cylinder. The pile, previous to its being let down, had two hoops put on its lower end, and the whole cut to receive the end of the iron dowell which stood in the rock; and from the side of this hole to the inside of the lower hoop, four pieces of iron were driven into the end of the pile, to prevent the timber at the sides of the dowell from giving way when the central pressure came upon the pile. On the four sides near the lower end of the pile, pieces were nailed on to increase its size to 22 inches, this being the diameter of the cylinder; by this means the hole was kept in its proper situation, and was found to pass exactly upon the dowell; it was then set hard to the rock by a stroke of a pile-engine. This completed fixing one main pile; a strong chain was then fastened to the top of the cylinder, and after the main pile was wedged down, to prevent it from rising, a strong purchase of ropes and blocks was applied to raise the cylinder out of the sand, but all the power that could be applied was ineffectual; a beam of 50 feet in length was then procured for a lever, the fulcrum of this lever was laid on the top of the main piles, the outer end of it was lifted up by ropes and blocks from the mast of a sloop; the chain from the top of the cylinder was now fixed to the inner end of the lever, and six men got on the outer end and set it in motion; the cylinder at length started, but before it moved it required a purchase of 50 tons; after it was worked a little by the lever, the ropes and blocks were again applied, and lifted up the cylinder over the top of the piles; the head of the pile was now forced against the inner side of the leading frame, and a screw-bolt put through both; the whole apparatus was then shifted to the head of the next main pile, and similar operations took place until the whole of the main piles were fixed.

The main piles having been all fixed at the bottom and fastened at the heads, temporary leading beams were bolted on the outside of the piles formerly described as being driven 15 or 20 feet apart all round the outside of the main leading frames; these spaces were

now filled up with piles set close side by side, and driven down to the rock; then the lower temporary leading frame was taken off, the upper one being left to steady the piles until the puddle was brought up in the cofferdam; the inside braces were now put in, they rested upon the brackets fastened to the main piles, and also on the top of these piles driven into the rock under the main stretching brace; the braces were, besides, prevented from floating by brackets nailed above them, and by stones laid on the temporary scaffolds. The outer row of piles in front of the cofferdam was begun by placing on a float made of long fir logs, from 40 to 50 feet long, and a foot square; these were fastened together by half logs spiked across them; the width of this float was 14 feet, which just filling the space between the rows of piles was thereby kept steady, and this was also the means of getting readily into a strait line the outer row of piles, which stood 15 or 20 feet apart; these being driven along, a leading beam was made by fishing, as formerly described, and bolted to the outside of these piles, on a level with the inside leading frame; a temporary leading frame was then fixed on the inside of the outer row of piles, one foot lower than the outside beam; there was then a scaffold erected on the top, in the space between the rows of piles; the pile-engine was then placed on this scaffold, and an outside leading beam bolted at the same level with the leading frame on the inside. The space between the first-mentioned piles was now filled up by others, set close together and driven down to the rock; by the time the outside and two return rows of piles at the angles were all driven, the bank and puddles on each side of the dam were brought forward to the front of the inner row of piles.

The connecting bolts were now put in, one through each main pile, opposite the middle of the leading frame, through which it went, and also across the puddle, and through the front leading beam on the outside of the outer row of piles; these connecting bolts were fastened by a strong cotterel through each end, with a strong iron plate under them; there were likewise two of these connecting bolts through each of the main piles in the front of the dam, one through each of the leading frames, and the other, one foot below low water of ordinary spring tides, at which place the lowest leading beam on the outer row of piles was fixed; the two rows of piles were kept together at the top by means of a strong piece of timber being joined on each side of the main pile on the inside of the dam, and being spiked down on the outside of the leading beams.

This description may no doubt appear to be too minutely detailed, but those engaged in a similar operation will not find it more than sufficient.

When the banks and cofferdam were completed, and the engine commanded the water, the ordinary expense of similar works was only to be incurred; a considerable quantity of rock was afterwards excavated, the masonry was executed in a workmanlike manner, the gates were constructed of the best English oak, and the lock has been constantly worked 10 years, and is now in a perfect state.

APPENDIX (E.)

COMPARATIVE PRICES of MATERIALS and RATE of WAGES in 1803, compared with 1814, on the CALEDONIAN CANAL.

ALTHOUGH every person must be aware of the material change which has taken place in the prices of provisions, labour and materials, yet it may be proper, in order to account for the apparent increase beyond the estimate of the canal works, to state the prices which actually took place where they are situated. I shall, therefore, insert a statement of facts furnished by Mr. Easton, whose accuracy may be relied on.

In the years 1803 and 1804, common labourers were paid 1*s.* 6*d.* per day; those habituated to canal work, 1*s.* 8*d.* to 2*s.* In the year 1812, similar labourers were paid from 3*s.* to 3*s.* 6*d.* per day. Piece-work, by the cubic yard, was paid at the rate of 3*d.* per cubic yard; in 1812, it cost 4½*d.* per cubic yard.

Carpenters were paid from 2*s.* 3*d.* to 2*s.* 6*d.* per day; for the last two years, 2*s.* 10*d.* to 3*s.* 4*d.* Masons were paid, in 1805, at the rate of 16*s.* per week; for the last three years, £.1. 1*s.* per week. Blacksmiths were paid at the rate of 2*s.* 6*d.* to 3*s.* per day; for the last two years, from 3*s.* 6*d.* to 4*s.*

Provisions (oatmeal), in 1803, from £.1. to £.1. 1*s.* per boll of eight stones or sixteen pecks; the average price for 1811 was £.1. 6*s.*; in 1812, £.1. 16*s.*; in 1813, £.1. 18*s.*; and other provisions in proportion.

Such horses as were used in 1805 cost from £.25. to £.30. each; in 1810, 1811 and 1812, similar horses cost from 40 to 50 guineas each. For provender; hay, in 1803 and 1804, cost 10*d.* per stone, and freight 3*d.*; for three or four years preceding 1812, it cost 1*s.* in autumn, and in the spring 1*s.* 8*d.*, and freight 4½*d.* per stone. Oats, in 1805 averaged 18*s.* per boll; in 1813, they were £.1. 5*s.*, and even £.2. 2*s.*

Country timber, in 1804, was 10*d.* to 1*s.* 2*d.* per cubic foot; in 1812, it cost 3*s.* 6*d.* per cubic foot. Foreign Baltic timber, in 1804, delivered at Corpach, 2*s.* 6½*d.*, at Clachmacharry, 2*s.* 4*d.* per cubic foot; in 1812, 7*s.* per cubic foot.—*This enormous enhancement of price arose from impolitic perseverance in an almost prohibitory duty, in favour of Cañada deals. This duty was continued (biennially renewed) till the parties claimed successfully a vested interest in the Canada timber trade, and the government were so imprudent as to yield to their influence. Thus has been inflicted a national injury, as forcing into consumption a bad article indispensable in building houses and for general purposes; and the same imprudence (as a necessary consequence) has rendered abortive the main advantage expected from the Caledonian Canal, which chiefly aimed at a saving of 2d. or 3d. per cubic foot (eight or ten per cent.) on all Baltic timber, for the benefit of the western ports and coast of Great Britain, and in the supply of all Ireland. This computation is indisputable, from the different prices of Baltic timber at the two ends of the Caledonian Canal; the enhanced price at Corpach (the west end) representing the cost and risk of carrying timber freights around the Orkneys.*

Oak timber for lock-gates, at first cost from 5*s.* to 8*s.* per cubic foot; in 1812, it cost from 10*s.* to 12*s.* Ropes, in 1805, were £.3. 15*s.* per cwt.; in 1812, they cost £.5. 12*s.* per cwt.

APPENDIX (F.)

DETAILED STATEMENT of the EXPENSE incurred in forming the HARECASTLE NEW TUNNEL.

	£.	s.	d.
Sinking 15 shafts 9 feet diameter	1,610	–	–
Driving heading through hill	7,057	–	–
Ditto cross-headings to carry off water	470	–	–
Ditto heading in coal measures to drain the sand at north end of tunnel	540	–	–
Excavating the body of the tunnel, and turning brick-work (including timber), length 2,926½ yards	43,435	–	–
Expense of towing-path	9,600	–	–
Ditto of railway, length 6½ miles	7,000	–	–
Ditto of providing bricks, mortar and centering	22,750	–	–
Labour upon mortar and centering	1,537	–	–
Carriage of materials	4,060	–	–
Expense of open cutting, entrances and turn-over bridges at each end of tunnel, erecting workshops, mortar mills, clay mills, engine houses, pumping water, damages of land, fences, agencies, &c.	14,622	–	–
£.	112,681	–	–

Number of bricks used in tunnel, shafts, towing-path, entrances, bridges, culverts, &c. - - - 8,814,000

Brinklow, February 25, 1833. *James Potter.*

APPENDIX (G. 1.)

EAU-BRINK NEW RIVER OR CUT.

OPINION and AWARD of *Joseph Huddart*, Esq., in pursuance of the Reference to him by Sir *Thomas Hyde Page*, Knt., and *Robert Mylne*, Esq.

To all to whom these presents shall come, I, Joseph Huddart, of Highbury Terrace, in the county of Middlesex, one of the Elder Brethren of the Trinity House, send greeting: Whereas by a deed poll or instrument in writing, bearing date on or about the fifth day of May last past, under the hands and seals of Sir Thomas Hyde Page, Knight, Captain in the Royal Engineers, and Robert Mylne, Esq., Civil Engineer, therein reciting, that by an Act of Parliament made and passed in the thirty-fifth year of the reign of his present Majesty, intituled, ' An Act for improving the Drainage of the Middle and South Levels, part of

'the Great Level of the Fens called Bedford Level, and the Low Lands adjoining or near 'to the said Levels, as also the Lands adjoining or near to the River Ouze, in the county 'of Norfolk, draining through the same to Sea by the Harbour of King's Lynn, in the 'said county; and for altering and improving the Navigation of the said River Ouze, 'from or near a place called Eau Brink, in the parish of Wiggenhall St. Mary, in the 'said county, to the said Harbour of King's Lynn; and for improving the Navigation of 'the several Rivers communicating with the said River Ouze,' the said Sir Thomas Hyde Page and Robert Mylne were nominated and appointed engineers for the purposes in the said Act expressed, and were thereby authorized and empowered (among other things) to determine, or mark and stake out the several dimensions, as well as the figure, form, situation and direction of a certain new river or cut to branch out of the said river Ouze, from the Common Salt Marsh, at or near a place called Eau Brink, in the parish of Wiggenhall St. Mary, in the said Act mentioned, through certain lands and grounds in that parish, and in the parishes of South Lynn All Saints and West Lynn Saint Peter, in the county of Norfolk, and to rejoin or fall into the then present course of the said river Ouze, at or near the harbour of King's Lynn aforesaid, for the free passage of the navigation and of the waters of the river Ouze, and also the length or extent of the several parts thereof, together with the manner of its junction with the present river Ouze, between German's Bridge and Eau Brink, at the upper end thereof, and between the lower parts of it and the Ball Wharf in the said Act mentioned, at the lower end thereof: And further reciting, that it was by the said Act (among other things) enacted, that the commissioners therein named or appointed for drainage should have full power and authority, and they were thereby authorized and required to make, do and execute, or cause to be made, done and executed, all such works, matters and things as the said Sir Thomas Hyde Page and Robert Mylne should agree upon and direct, for the better security and more effectual preservation of the town and harbour of King's Lynn aforesaid, and the navigation from thence to the open sea, from all possible damage or injury, in consequence of the making of the said new river or cut: And further reciting, that it was by the said Act also enacted, that in all cases where there should be any difference of opinion between the said Sir Thomas Hyde Page and Robert Mylne touching any of the works, matters and things in the said Act mentioned, save and except as to the dimensions and general form of the said new river or cut, which were and was to be such as in the said Act directed, and no other, it should be lawful for the two engineers so differing in opinion, and they were thereby required to call in to their assistance some other able and experienced engineer, by way of umpire, who, after hearing and duly considering the whole of the matter on which such difference of opinion should have arisen, should give his opinion in writing as to the works, matters or things requisite or fit to be done, and the mode of executing the same, or on whatever else might have been the cause or subject of the reference to him; and his opinion so given should be final and conclusive, and the works, matters and things in question should be done and executed conformably thereto, in all respects whatsoever: And further reciting, that a difference of opinion had arisen between the said Sir Thomas Hyde Page and the said Robert Mylne, touching several of the works, matters and things mentioned in and requisite, or fit to be done, under or in consequence of the said Act of Parliament, and

the mode of executing the same; and therefore the said Sir Thomas Hyde Page and Robert Mylne had found it necessary, and agreed, in pursuance of and obedience to the said Act, and the power and requisition therein contained, to call in to their assistance and appoint another able and experienced engineer, by way of umpire, to hear and consider the whole of the matter upon which such difference of opinion had arisen; and to give his opinion in writing as to the said works, matters or things requisite or fit to be done, and the mode of executing the same, or on whatever else might be the cause or subject of reference to him: Therefore, by the said deed poll, or instrument in writing, now in recital, it is witnessed, that in consideration of the premises, and for effecting the purposes of the said recited Act of Parliament, they, the said Sir Thomas Hyde Page and Robert Mylne, in exercise and execution of the power or authority given by and in compliance with and obedience to the requisition or direction contained in the said Act, did thereby nominate, appoint and call in to their assistance me, the said Joseph Huddart, by way of umpire, to hear and duly consider the whole of the matters on which such difference of opinion had arisen between them, the said Sir Thomas Hyde Page and Robert Mylne, as therein and hereinbefore is stated or expressed; and to give my opinion in writing as to the works, matters or things requisite or fit to be done, under or in consequence of the said Act of Parliament, and the mode of executing the same, or on whatever else was or might be the cause or subject of reference to me, as in and by the said deed poll, or instrument in writing, reference being thereunto had, will more fully appear.

And whereas I have been attended by the said Sir Thomas Hyde Page and Robert Mylne, who have severally stated and represented to me, that the differences of opinion which have arisen between them in relation to the matters aforesaid are as follow; that is to say, they differ as to the points of junction of the intended new river or cut with the river Ouze, at both ends of such new river or cut; and also as to the dimensions of the excavated part of the intended new river or cut; and concerning the width of the forelands and base of embankment at the lower end of the intended new river or cut; (but they have agreed that the width of such forelands and base of embankment shall be 278 yards from bank to bank, at the top of the embankments;) and also they differ concerning the slope or base of the embankments at the upper end of the said intended new river or cut:

Now know ye, that I have heard and duly considered the whole of the matter on which such differences of opinion as aforesaid have arisen, and do by these presents give my opinion in writing as to the works, matters or things requisite or fit to be done, and the mode of executing the same, and on the whole of the cause or subject of reference to me as aforesaid, as follows:

Premising, that I refer in sundry parts of this my opinion to the annexed drawing, and that I also refer to certain poles by me seen and examined, and which (having numbers cut in them from the lower towards the upper ends thereof respectively) are placed in the middle line of the intended new river or cut, as agreed by the said Sir

Thomas Hyde Page and Robert Mylne (and which middle line I entirely approve of); I declare my opinion, first, that the point of junction of the intended new river or cut with the present channel near King's Lynn ought to be 860 feet nearer to the harbour of King's Lynn than the lowest pole marked number 4, and which point is also 1,500 feet nearer to Lynn than pole number 6, which is at the north end of the said middle line of the said intended new river or cut; and I am also of opinion, that at the above-mentioned point of junction the several dimensions of the said intended new river or cut ought to be as follows: viz.—

	Feet.
The width of the Navigable Channel - - - - - -	296
The East Foreland - - - - - - - - - -	209
The West Foreland - - - - - - - - - -	200
The base or slope of the East Embankment - - -	64
The base or slope of the West Embankment - - -	65
	834

Those dimensions being together equal to 278 yards, as directed by the Act of Parliament above referred to, in relation to the width of the channel to be formed by the said new river or cut at the junction with the present channel near King's Lynn.

I am further of opinion, that the point of junction of the said intended new river or cut with the present channel at the upper end, near Eau Brink, ought to be 700 feet farther up the river than the southernmost pole number 37, in the middle line; which point of junction is in the same arc of the circle continued as the middle line already set out; at which last-mentioned point the several dimensions of the said intended new river or cut ought, in my opinion, to be as follows:

	Feet.
The width of the Navigable Channel should be - - -	204
The East Foreland, determined by the Act of Parliament -	60
The West Foreland, also determined by the Act of Parliament	80
The base or slope of the East Embankment - - -	13
The base or slope of the West Embankment - - -	13
	370

Those dimensions last described being together 370 feet, as directed by the said Act of Parliament in relation to the breadth from bank to bank, at the upper end of the said new river or cut.

Nota Bene.—I am of opinion, that the new embankments, forelands and channel of the new river ought to form fair curves in joining the banks and channel of the present river, both at the upper and lower ends of the said intended new river or cut.

Thirdly. I am of opinion, that the dimensions in the following Table (A.) ought to be attended to and adopted in the execution of the work, the said Table containing the dimensions in feet and inches of a sufficient number of sections, in order that the new river or cut may be made throughout of an increasing width, in a regular and uniform manner, as directed by the said Act, according to the Drawing above referred to, signed by me, and hereunto annexed, and also conformably to the following Table:—

TABLE (A.)

Dimensions in Feet and Inches, at the Junctions with the old and new River, and at the following Sections, distinguished by the Numbers on the Poles placed on the Middle Line of the Cut.	Internal Base or Slope of the West Bank.		The West Foreland.		The Width of the Cut at the Height of Water Line A. B.		The East Foreland.		Internal Base or Slope of the East Bank.		The Width from Bank to Bank.	
	Feet.	In.	Feet.	In.	Feet.	In.	Feet.	In.	Feet.	In.	Feet.	In.
At the lower junction, near Lynn - - -	65	–	200	–	296	–	209	–	64	–	834	–
At pole marked V. - -	57	–	186	–	266	–	199	4	57	–	765	4
„ - - - VI. - -	55	–	184	–	263	–	196	–	55	–	753	–
„ - - - XV. -	39	–	148	–	241	4	148	–	38	–	614	4
„ - - - XXII. -	26	6	117	–	224	–	108	–	26	–	501	6
„ - - - XXXI. -	21	–	103	–	218	–	91	–	21	–	454	–
„ - - - XXXVII.	15	–	87	–	211	–	69	–	15	–	397	–
At the upper junction, near Eau Brink - - -	13	–	80	–	204	–	60	–	13	–	370	–

Fourthly. I declare that what is written on the said Plan, hereto annexed, is to be taken as part of my opinion on the matters referred to me as aforesaid; and in further illustration of this my opinion, I desire it may be observed, that the slope or base of the sides of the new river or cut is to be three feet base for one foot in height to the depth of low water, every where in the strait part of the cut; and below low water, the sides and bottom to be a fair curve, deepest in the middle; but in the circular part at the upper end of the new river or cut, I have diminished the base or slope of the sides on the east, and increased the base or slope of the sides on the west part or side, which will have the effect of removing the greatest depth of water from the middle line, as represented in the sections and following Table (B.), in which I have inserted all the poles that are now standing above the strait part of the cut.

TABLE (B.)

POLE.	The greatest Depth on the East Side of the Pole.		Base on the East Side of the Cut, for Six Feet in Height.		Base on the West Side of the Cut, for Six Feet in Height.	
	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.
XXII. - [*See* Section] -	4	–	17	6	18	9
XXVIII. - - - - -	8	–	16	9	19	3
XXIX. - - - - -	11	8	16	–	20	–
XXX. - - - - -	14	11	15	6	20	6
XXXI. - [*See* Section] -	17	7	15	–	21	–
XXXIII. - - - - -	19	5	14	9	21	3
XXXIV. - - - - -	20	6	14	6	21	6
XXXV. - - - - -	21	–	14	6	21	9
XXXVI. - - - - -	21	3	14	5	21	10
XXXVII. [*See* Section] -	20	9	14	6	21	8

Note,—further, That I have left the outside of the embankment in an undefined state. The breadth at the top and the outward slope of the bank must depend upon the quantity of earth to be excavated, which is the business of the engineers who shall have the execution of the work; but, in my opinion, the height should be eight feet three inches above high-water line A B in the section, or six feet above the fifteen-feet tide.

In witness whereof, I, the said Joseph Huddart, have hereunto set my hand and seal this tenth day of September, in the year of our Lord One thousand eight hundred and four.

Joseph (L. S.) *Huddart.*

Sealed and delivered by the within-named Joseph Huddart, in the presence of—

Ambrose Weston, Fenchurch-street.
Charles Mallet, his Clerk.

Taken and acknowledged by Joseph Huddart, within named, at the Public Office in Southampton Buildings, this tenth day of September, One thousand eight hundred and four, before me,

J. S. Harvey.

Enrolled in his Majesty's High Court of Chancery, the twenty-sixth day of September, in the year of our Lord One thousand eight hundred and four, being first duly stamped, according to the tenor of the statutes made for that purpose.

J. Mitford.

APPENDIX (G. 2.)

EAU-BRINK CUT.

REPORT of Mr. *Telford*, A. D. 1823.

WHETHER the umpire had or had not any legal right to fix other dimensions for the Eau-Brink Cut than those specified in the Act of Parliament, I do not pretend to determine; but that in his award he did so, is obvious from the following statement:—

Dimensions by the Act.		Dimensions by Captain Huddart's Award.	Differences.
LOWER END.		Feet.	Feet.
Width of navigable canal,	484 feet	- - 296 - -	- - 188
East foreland - -	150	- - 209 - -	- - 59
West ditto - -	100	- - 200 - -	- - 100
Base of east bank -	50	- - 64 - -	- - 14
Ditto west ditto -	50	- - 65 - -	- - 15
278 yards, equal to	834 feet	834 feet -	At level A B on Captain Huddart's section or line of ground surface, on his proposed Plan.
UPPER END.		Feet.	Feet.
Width of navigable canal,	230 feet	- - 204 - -	- - 26
East foreland - -	60	- - 60 - -	- - —
West ditto - -	80	- - 80 - -	- - —
Base of east bank -	—	- - 13 - -	- - 13
Ditto west ditto -	—	- - 13 - -	- - 13

By the above dimensions it will appear that at the lower end next Lynn, the general width on the surface or ground line has been adhered to by the award of Captain Huddart, viz. 278 yards or 834 feet; but that in the distribution, the dimensions have been changed greatly to the disadvantage of the waterway; that is to say, 188 feet have been taken from the channel or waterway, and added to the forelands and bank slopes, which, being seldom or never covered with water, are of no advantage to the drainage, navigation or Lynn harbour.

At the upper end, near Eau-Brink, 26 feet have been taken from the channel or waterway, and the total width is only made out by taking in the bank slopes not mentioned in the Act.

Thus we find that the lineal dimensions have been changed, and that for the depth or shape of the cut vertically, no dimensions or directions are given in the Act; but it is fairly presumable that the intention was, that the shape and capacity of the section were to be such as best to answer the purposes of drainage, navigation, and the harbour of Lynn.

Now the shape fixed on by the umpire was not the fittest for any of these purposes; being the segment of a large circle, instead of that of a trapezium, there is little capacity for water near the bottom, which very much limits its effects in the latter part of the ebb, when it is most beneficial for drainage, scouring the bottom, and also the harbour of Lynn. This shape also checks the first of the flood; it appears, therefore, to have been injudiciously selected. The form best adapted for the above-mentioned purposes is to have the bottom a flat surface, and so broad as only to leave room sufficient for the slopes to the sides of the cut, as it ought to have been so much deeper as to leave a sufficient width, say 200 feet at low-water. The insufficiency of the capacity is also evident from the comparison of sectional areas:

	Feet.	Difference.
Sectional area of river Ouze at the ferry at low water -	3,930	
Ditto - - of lower end of cut - - at ditto - -	989	
		2,941
Ditto - - of river at ferry - - - - at high water,	14,569	
Ditto - - of lower end of cut - - - ditto -	4,187	
		10,382
Ditto - - near St. German's Bridge, at low water -	2,253	
Ditto - - ditto upper end of cut - - - ditto - -	864	
		1,389
Ditto - - ditto St. German's - - - high water,	6,413	
Ditto - - ditto cut - - - - - - - - - ditto - -	2,958	
		3,455

	Ft.	In.	
Clear waterway of all the sluices emptying into West river side - - - - - - - -	97	1	314 ft. 3 in.
Ditto - East side - - - - - - - -	32	2	
Ditto - Denver Sluice - - - - - - -	85	–	
Ditto - Hundred-foot River - - - - - -	100	–	

Width of the river at low water, between Denver Sluice and Eau Brink - - - - - - - - - - 200 feet.

Width of river between German's Bridge and Eau Brink Cut - 230 feet.

Upper end of new cut at ditto, where there was a fall of 2 ft. 4 in. from Eau Brink to Lynn - - - - - - - -	128 feet.
Fall from Denver Sluice to upper end of cut, 6 ft. 3 in., distance 10 miles - - - - - - - -	7½ inches per mile.
Ditto upper end of cut to Lynn - - 7 ft. 5 in. - ditto 2¾ ditto - - - - - - -	32 inches - ditto.
Average fall of a regular inclined plane - - -	13 inches - ditto.
Velocity between Denver Sluice and entrance to cut, at two hours after high-water - - - - - -	2½ feet per second.
Ditto from entrance of cut to Lynn - - - -	5 - - ditto.

Thus comparing the lineal dimensions, sectional areas, fall and velocity of the river, with those of the waterway of the Eau-Brink Cut, it is obvious that the latter is very inadequate to the purpose for which it was intended; that it acts as a dam of from four to five feet, thereby greatly impeding the drainage in the latter part of the ebb, when most required, and by checking the entrance and diminishing the quantity of tidal water, its useful scouring effects upon the river bottom and outfall are rendered much less powerful, and particularly injurious to the harbour of Lynn, in not removing the great mass of sand which has accumulated along the town quays since the opening of the Eau-Brink Cut, and maintaining that harbour in its usual depth.

From all the foregoing circumstances, it is evident that to obtain the advantages for which the Eau-Brink Cut was intended, as regards the drainage, navigation and outfall, it is absolutely necessary that its sectional area be increased.

(signed) *Thomas Telford.*

July 5th, 1823.

Appendix (G. 3.)

REMARKS on the Nene Outfall, by *J. R.*, August 1830.

Since the Dissolution of Parliament, I have accompanied Mr. Telford in visiting an operation of more interest than ordinary in civil engineering.

If you cut a canal, you are sure that the removal of earth and the usual apparatus of locks will attain your object; but the improvement of harbours, and of drainage by rivers, depends on management and direction of natural causes and effects; in which, I may say, observation had been so torpid, that till twenty years since, much more harm than good had been the result of interference. All the Reports of Mr. Smeaton, and some made scarcely sixteen years since, prove that in large drainages near the sea, natural outlets or rivers are always recommended to be stopped by dams and sluices, to prevent the tide from entering; which obstacles equally prevented the drainage water from free passage outward.

Three inches fall (downward slope) in a mile makes water move slowly; at four inches declivity in a mile, water acquires a moderate velocity, sufficient for any drainage operation; so that the *sill* (threshold) of a sluice, if laid a yard too high, will prevent the

natural drainage of 12 miles above it (three inches to a mile). On the same principle, if a drainage outlet, obstructed by what may be almost deemed the *caprice* of winds and tides, and of accumulated sand-banks in consequence, shall double its length, and creep through a dubious crooked channel, it is evident that a three or four-inch fall may become one inch, which is ineffectual.

The sound principle which results from these facts is, to give free ingress to the tidal water, guarding against inundation by raising the banks of your river, and also straitening its course, so as to lose no downfall. This increased downfall and increased tidal water is made to bear directly upon the old sand-banks; and if the connection with deep water can be established in this manner, you obtain a harbour of easy access, and the old-fashioned precarious drainage of land by windmills becomes unnecessary, the dams which previously hindered daily drainage at low-water being for ever removed.

All this was to be seen in progress below Wisbech and Long-Sutton-bridge, and the impetuous outfall of the water in the recess of a spring-tide had forced its way through the sands in the beginning of August 1830. With view to this event, the old channel of the river Nene had been boldly dammed across in the middle of July, and the current turned into the strait cut prepared for it. All this constitutes the "Nene Outfall." When I saw it meet the sea, four miles below the washway (now the drawbridge at Long Sutton) at three-quarters ebb, the torrent rushed down four feet in the last quarter of a mile; this of course carries off the sand daily, and by the law of nature the four-feet fall will recede inland, until nearly a uniform inclination or slope shall penetrate to Wisbech, which will become a sea-port of importance; and above it 180,000 or 200,000 acres of fen-land will retain nothing of its hitherto nature, except unparalleled fertility.

John Rickman.

APPENDIX (G. 4.)

MEMOIR of the NENE OUTFALL and the NORTH LEVEL DRAINAGE.

By *Tycho Wing*, Esq. of Thorney Abbey.

THE Nene Outfall is a new tidal channel for the discharge of the waters of the river Nene into the sea, and is carried entirely through the light incohesive sands which border the Lincolnshire coast; the portion of it artificially formed commences at a part of the old river called Kinderley's Cut, near Buckworth's Sluice, about six miles below Wisbech, in the Isle of Ely, and extends to Crabhole, a distance of six miles and a half; from thence it has shaped for itself a natural channel, in length about a mile and a half into the Wisbech Eye, which is an inlet of the German Ocean.

The excavation of this work by digging was commenced in August 1827, and was completed to the depth of about 11 feet in June 1830, when the old channel was closed; the course of the new river was afterwards deepened as much as 12 feet and upwards by the scour of the tidal current; and its sides were secured by a thick coating of stones, brought partly from a cliff near the Humber, and partly from the Duke of Bedford's estate at Wansford, in the county of Huntingdon.

The width of the bottom of the river is 200 feet near the lower end, and 140 feet at the upper end near Kinderley's Cut; the depth from the surface of the adjacent land to the bed of the river is about 24 feet throughout; the width at the top varies from 200 to 300 feet.

An ordinary spring-tide rises about 22 feet at the lower extremity next the sea, and 18 feet at the junction with Kinderley's Cut.

The results of this measure are—

A bridge has been made over the new channel at Sutton-Wash, in Lincolnshire, and an embankment carried across the estuary to Cross Keys, in Norfolk, forming a new line of excellent road between Norfolk and Lincolnshire, subject to no interruptions, instead of the ancient dangerous ford through a tidal and variable channel, or the very circuitous route through Wisbech.

About 1,500 acres of fertile marsh lands have been embanked from the sea, and are now in cultivation, and producing yearly excellent crops of grain; that an additional tract of about 2,000 acres is fit for inclosure, and about 4,000 acres more are rapidly becoming so.

In place of the navigation through the old channel, which was extremely tedious and dangerous, and capable only of affording a passage at spring-tides, and with a favourable wind, to vessels drawing at the utmost six feet of water, and carrying sixty tons, there is now a safe and daily communication between Wisbech and the sea at all periods of the tides, and in all weather, for vessels of the above burthen, and on spring-tides for ships of much larger capacity, and drawing not less than 14 feet of water. Vessels carrying 400 tons reach Sutton-Wash on spring-tides, and might arrive at Wisbech, if sufficient pains were taken to improve the river upwards from the Nene Outfall. Wisbech would thus become the great emporium for the counties of Cambridge, Norfolk and Lincoln: the trade of the port, which before the Nene Outfall was made was not more than 50,000 tons a year, has since progressively increased, and reached in the last year to 108,000 tons; great exertions have also been made, and expensive works executed by the Governors of Guy's Hospital (to whom the adjoining land belongs), to improve the accommodation for vessels, and facilitate the shipping and delivery of cargoes at Sutton Wash; for this purpose a magnificent wharf has been built, with ample accommodation of storehouses and granaries. It is unnecessary to point out how much the convenience and prosperity of the surrounding districts is advanced by this extension of trade, and by the means of accelerated intercourse with other places.

In consequence of the more rapid discharge of the upland floods through the Nene Outfall, the danger of inundation by a breach of bank is incalculably diminished to the fens on each side of the river Nene, between Peterborough and Wisbech.

The value and security of the rich meadow lands in Moreton's Leam Wash,—being the space set apart as a receptacle in winter for the upland floods, in their passage through

the fens from Peterborough to Wisbech, and containing about 3,500 acres (and even of the upland meadows beyond Peterborough), is greatly augmented.

But the most important result of the whole is, *that* the water in the new channel ebbs out every day fully ten feet lower than it formerly did in the old channel, immediately opposite to the South-Holland and North Level sluices, which are the outlets for about 100,000 acres of fen lands, lying between the rivers Nene and Welland, and that the means have been thereby afforded to that extensive tract of a perfect natural drainage, which was previously very ill accomplished by means of an expensive and complicated but ineffectual system of windmills and steam-engines.

The North Level, containing 48,000 acres, and situate in the contiguous parts of the counties of Cambridge, Northampton and Lincoln, was the first great division of these fens which proceeded to avail itself of the advantages placed within its reach. A new sluice was built for the utterance of the waters of this level into the Nene Outfall, no less than eight feet deeper than the sluice by which they were formerly conveyed into the old channel of the river; the width of the waterway of the old sluice was seventeen feet; that of the new sluice is thirty-six feet.

A new main drain was formed leading to this sluice from Clows-Cross, at which point all the waters of the North Level are collected.

The length of this drain is eight miles and a quarter; the length of Old Shire drain, for which it is substituted, and which commenced and terminated by a very circuitous course at nearly the same points, was about twelve miles. The new drain is eight feet deeper than the old drain, and its capacity in equal lengths more than six times as great; its bed is an inclined plane, having a declivity from Clows-Cross of four inches per mile.

From Clows-Cross the new drainage diverges by two channels, called respectively the New-South-Eau and the New-Wryde, which receive in their course the waters from every part of the North Level, including Newborough, Bow Fen and Great Portsand. As compared with the old drains, namely, the Old South-Eau and the counter drain by Guyhirn, these new lines possess a superiority over the old ones, fully commensurate with that stated in the comparison between the Old Shire drain and the New Main drain.

The district of Wisbech hundred, comprising about 15,000 acres, has also made terms with the Commissioners of the North Level drainage for a participation in the use of the main drain.

All these drains are navigable, which was not the case with the old ones, and afford a cheap and ready transit for coals, and other articles of daily consumption.

These works for the drainage of the North Level were commenced in July 1830, and completed in 1834; their effects upon the productiveness of the soil, and on the welfare and comfort of the inhabitants, surpass all previous expectation.

The expense of executing the Nene Outfall was about £. 200,000; that of the North Level drains about £. 150,000.

The Nene Outfall channel was projected by the late Mr. Rennie in 1814, and was executed jointly by Mr. Telford and the present Sir John Rennie; but the scheme of the North Level drainage was eminently the work of Mr. Telford; and was undertaken upon his advice and responsibility, when only a few of the persons engaged in the Nene Outfall believed that the latter could be made, or, if made, maintained: Mr. Telford distinguished himself then by his foresight and judicious counsels at the most critical periods of that great measure, by his unfailing confidence in its success, and by the boldness and sagacity which prompted him to advise the making of the North Level drainage in full expectation of the results, for the sake of which the Nene Outfall was undertaken, and which are now realized to the extent of the most sanguine hopes.

John, the present and sixth Duke of Bedford, has been the great patron and promoter of both undertakings.

Tycho Wing.
(1833, continued to 1837.)

APPENDIX (G. 5.)

DESTRUCTION of FRESH-WATER FISH at PETERBOROUGH.

AN incidental remark is sometimes productive of information which otherwise might not have been given, or not in so convincing a manner, by any formal description; of this kind is the following explanation of the destruction of fresh-water fish at Peterborough, which, by a traveller, had been naturally but erroneously attributed to the greater penetration inland of salt water, by reason of the improved Nene Outfall; the refutation of which error has produced the following lively explanation of the nature of the coast, or sea-outline of Fens or marsh-lands in the course of their usual formation.

EXTRACT of a LETTER from *Tycho Wing*, Esq., dated 29 Dec. 1837.

The destruction of the fish at Peterborough was occasioned by an influx of salt water, before the Nene Outfall was made; and it is remarkable, that the effect of that work has been to diminish the saltness of the water at and above Wisbech; formerly, the tide having surmounted the accumulation of high sands at the mouth of the river, came up in one great wave to Wisbech, and as there were many shoals in the river upwards, this wave, breaking at once over them, filled the river and the adjacent Wash between Guyhirn and Peterborough with salt water, which could not find a way back again over the shoals, but remained for many weeks, especially in summer, and killed all the fish; but now, by the lowering of the outfall, the fresh water is drawn many miles lower down the stream on every ebb of the tide; and as the latter returns in a slow and gradual manner, which is felt in the river from the first commencement of flood-tide in the Eye anchorage, the column of fresh water is slowly repelled up the river, and by its accumulation checks the advance of the salt water,—to the great benefit not of the fish only, but of men and cattle, on both sides of the Nene River from Wisbech to Peterborough (including

nearly all the North Level and great part of the Middle Level), which depend entirely on the Nene for a supply of this important article through the whole of the summer; for the water in the Nene between Guyhirn and Peterborough being higher than the surface of the adjacent fen lands, is abstracted by sluices through the banks, and then conveyed by appropriate channels into each district. The scarcity of fish and eels at Peterborough arises from unfair obstructions at the Mills above, almost all the way to Northampton.

Appendix (H.)

REPORT from the Select Committee appointed to consider how far it is expedient to extend the Patent granted for Morton's Slip; with Extracts of the Evidence adduced before the said Committee.—(April 1832.)

Your Committee caused Mr. Morton to produce before them his books and accounts, showing his receipts and expenditure arising from his invention, from the date of his obtaining his patent to the present period; they also caused him to lay before them the patent itself, and the other papers stated in the evidence, and they called before them and examined Mr. Morton himself, and several other persons whom they considered likely to be able to give the most correct information on the subject.

After giving to the whole the most mature consideration, your Committee have come to the following conclusion: That Mr. Morton's invention of the patent slip in question is of the most ingenious and valuable description, of the highest advantage to the shipping interests of this maritime country (insomuch that the operation of placing a ship in a situation to be repaired, which previously to this invention cost £.170, can now, by this means, be effected for £.3), and it is equally valuable and applicable for the larger ships of war as for the mercantile marine; that owing, however, to the difficulty of drawing attention to this invention, and to bringing it into use at first, as explained in the evidence, the patentee appears not to have derived any profit whatever from his patent for the first six years, and during the whole period of its duration only £.5,737.

That an invention of such ingenuity, of such simplicity of construction, though of such extensive and important benefit, is well deserving greater reward from the public than has hitherto been received by Mr. Morton, or is likely to be received by him under his patent during the short remainder of its duration; but your Committee entertaining the strongest and most decided impression of the impolicy of granting renewal of patents under any circumstances, particularly on a plea of their not having produced sufficient rewards to the patentees, and observing that the instances of such indulgences having been granted are extremely rare, there having been only two since the year 1800, your Committee do not consider it expedient to recommend to the House to extend the patent granted for Morton's Slip.

Your Committee trust, however, they may be permitted to add the expression of their hope, that some other means may be adopted to obtain for Mr. Morton a more adequate

pecuniary recompense for the great benefit his invention has conferred on the public, and the shipping interest in particular, than he appears to have derived from his patent, as before stated.

Your Committee beg to observe, that the feeling they so strongly entertain of the general impolicy and impropriety of the Legislature acceding to applications for renewal of patents, without the fullest consideration, induces them earnestly to recommend to the House to establish, as one of their Standing Orders, That no Bill for the renewal of a patent be read a second time until it shall have been investigated and reported upon by a Select Committee.

MINUTES OF EVIDENCE.

Mr. *Thomas Morton*, called in; and examined.

CAN you state to the Committee how many of your patent slips you have put down, and in what places?

Aberdeen - -	1	Dysart - - -	1	Jarrow - - -	1	Quebec - - -	1
Arbroath - -	1	Edinburgh - -	1	Leith - - -	2	Shields - - -	1
Ayr - - -	1	(Union Canal.)		Liverpool - -	1	Shoreham - -	1
Berwick - -	1	Glasgow - -	2	Londonderry -	1	Sunderland -	2
Bo'ness - -	1	Goole - - -	1	Lowestoff - -	1	Swansea - -	1
Carnarvon -	1	Harwich - -	1	Maryport - -	1	Sydney - - -	1
Cork - - -	2	Hull - - - -	2	Montrose - -	1	Waterford - -	1
Dublin - -	2	Ipswich - - -	2	Newcastle - -	2	Whitehaven -	1
Dumbarton -	2	Irvine - - -	1	Portsmouth -	1	Workington -	2

How many in the whole?—About 40.

What is the largest class of vessels for which you have constructed these slips?—The largest class is 800 tons.

Did you find that succeed?—Yes; but I am not aware whether they have hauled up so large a vessel as yet.

Do you suppose, from your knowledge of the success of the slip, that its principle can be applied to ships of a greater size—such as ships of war?—Yes, I make no doubt of it.

You have no hesitation, from what you know, to recommend it to haul up ships of much greater size than any it has been laid down for?—No doubt of it.

Could you apply it also to steam vessels of any kind?—Most undoubtedly.

Have you ever done so?—Yes; there have been steam vessels hauled up in Aberdeen and other places.

Can you give the Committee any idea of the expense that would be incurred in laying down one of these slips?—It will depend on whether it is for large vessels.

Have you a statement, or table of the expense of constructing them, and of the different rates?—Yes; I have a table for all sizes under 500 tons. The expense of constructing a slip for vessels of 100 tons is £.450; for 200 tons, £.600; 300 tons, £.800; 400 tons,

£. 1,000; 500 tons, £. 1,100. These sums, however, are exclusive of the expense of preparing the ground.

You say you completed one for an 800 tons ship; what was the expense of that slip?—It was £. 1,900. Most of them are constructed to contain two vessels at the same time.

You have given a statement for a vessel of 500 tons; you have put down £. 1,100, does that allude to two vessels of that size?—It does.

Then it is a slip for vessels of 800 tons, capable of holding two of that size, that costs £. 1,900?—Yes.

When you have done the work yourself, have you found that there is a very great variation in the whole price from the difference in the ground in any of the places you have had to lay it down; what is the highest you have paid, and what the lowest for preparing the ground?—From £. 200 to £. 300.

Do you consider this machine of yours an original invention, or an improvement in principle?—Hauling up ships is an old practice; my machine is an improved method of doing so with greater facility and safety. It possesses the following advantages:—

1. A durable and substantial slip may be constructed, under favourable circumstances, at about one-tenth of the expense of a dry dock, and be laid down in situations where it is almost impossible, from the nature of the ground, or the want of a rise and fall of tide, to have a dock built.

2. The whole apparatus can be removed from one place to another, and be carried on ship-board.

3. Where a sufficient length of slip can be obtained, a number of vessels may be upon it at once; and, in point of fact, two or more are often upon the slips already constructed, and under repair, at the same time.

4. Among the other advantages peculiar to the slip, it may be observed, that, every part of the vessel being above ground, the air has a free circulation to her bottom and all around her; in executing the repairs, the men work with much more comfort, and of course more expeditiously; and in winter especially; they have better and longer light than within the walls of a dry dock; while considerable time is saved in the carriage of the necessary materials. The vessel, in short, is in a similar situation to one upon a building slip.

5. No previous preparation of bilge-ways is necessary, as the vessel is blocked upon her keel, the same as if in a dock; and she is exposed to no strain whatever, the mechanical power being solely attached to the carriage which supports her, and upon which she is hauled up.

6. A ship may be hauled up, have her bottom inspected, and even get a trifling repair, and be launched the same tide; and the process of repairing one vessel is never interrupted by the hauling up of another, an interruption which takes place in docks, from the necessity of letting in the water when another vessel is to be admitted.

7. A vessel is hauled up at the rate of two and a half to five feet per minute, by six men to every 100 tons; so that the expense, both of taking up and launching one of from 300 to 500 tons, does not exceed forty shillings.

Captain *Basil Hall*, R. N., examined.

WOULD you have the kindness to give the Committee any information on this subject, if you have seen this in use?—I have seen many vessels hauled up with it.

Where?—Four or five at Leith, and several at New York.

Is the one at New York precisely the same?—In some of the minor details it is different; at first I considered them improvements, but not afterwards.

On the same principle?—Yes.

Did they have it from Mr. Morton?—I am not aware of that; they never spoke of it except as his invention.

What is the largest vessel you saw hauled up?—I saw a vessel of 800 tons hauled up at New York, which, I believe, is larger than any drawn out of the water in this country on Morton's slip.

Was it with great facility?—With perfect ease, safety and expedition.

Did she come in the ways readily?—She came in it very readily. I may here observe, that the whole frame-work, on which the ship rests, is first sunk below the surface of the water, and then placed under the vessel; it is now secured firmly, and then this frame-work is pulled on the slip, with the ship upon it.

The vessel is brought on it?—Yes; and then the frame-work is drawn on the slip. The purchases are applied exclusively to the frame, never to the ship herself; and by this means all strain upon the vessel is avoided.

At what distance was this vessel of 800 tons fitted into her frame from the water's edge?—I can hardly say. Of course, in high water, the slip extended for a space between 50 and 100 yards into the water; the rise and fall is not very considerable at New York, eight or ten feet, I believe; but she was placed in this frame securely nearly at high water.

How long were they doing that?—I cannot exactly recollect; I think it was under two hours they had her up high and dry from the first commencement. The fact is they had become very expert at the operation, and they drew her on very easily.

When once they began to heave they made no stop?—She was hove up by steam. The slip at New York is connected with a set of flour-mills, and when a vessel is to be hauled up they arrange so as to suit the tide, and having turned off the steam from the mills, apply it to the purchase to draw the ship up. The only material difference that I saw between the two slips was, that instead of using a flexible chain, such as Mr. Morton makes use of, they employ a stiff chain, composed of large and powerful links, which are not capable of turning round the barrel, though they possess a slight degree of flexure. It is furnished with holes which fit the cogs of a wheel. Their object in this contrivance is to possess the power of pushing the vessel off as well as pulling her on. The nature of the ground there would have caused considerable expense to have made a slip of sufficient inclination for the ship to launch herself; some vessels, indeed, go off without this thrust, but others will not go without it. At high water, when it is required to launch a vessel to save the tide, she is pushed off merely by turning the machinery in the opposite direction, when the thick chain then acts as a forcing bar. There is room at the back yard where this chain or bar lies over tressels. Upon one occasion, just as the vessel had nearly reached

her station, I forget from what cause, one of the links snapped, but the palls caught her; she did not run back into the water.

When they are endeavouring to get a vessel off, they have the means of keeping these palls up?—The mode of launching is to set on the engine and pull the ship up for a few inches, then lift up the palls; if she does not go off then by herself, they turn the engine slowly the other way, and she is readily pushed off the slip.

Do you consider it original?—As far as I know, it is so; I have seen nothing like it of any invention.

You think it might be applied to vessels of any size?—Certainly; I have not the least doubt that Mr. Morton, or any person of experience, could make one to pull up a three-decker, for I really see no limit. The principle is to bring the frame under the vessel, and support her on it, and then to pull, not the vessel, but the frame, on the slip.

Can you state the advantages, if any, that this has over the docks?—One advantage is in the difference of the original cost; but, practically speaking, I think it a great advantage to have a vessel above ground, instead of having her sunk below the surface. We may also calculate upon an hour or an hour and a half of day-light being gained every morning and evening. I have watched the workmen at sunset, and there appeared to be a clear gain of an hour and a half of good light to work by, owing to the lower part of the vessel being above ground instead of being sunk into it. It is sometimes of importance also that the vessel's bottom should dry quickly; now the dock is wet, but on the slip the vessel is drawn so far up, that the air passes freely through her, and the planks soon become dry. I have observed in most docks a good deal of awkwardness in handling large timber in the lower part of the dock. Long spars also are very difficult to be got up and down, whereas when she rests on Morton's slip, the vessel is as commodiously situated as if she were in the building dock.

Have they any sheds over these slips in America?—No, none.

Upon the whole, you consider it more advantageous than a dock?—Certainly. I am aware that in countries where the rise and fall of the tide is very small, an enormous deal of trouble is saved by avoiding the labour of pumping the water out of dock.

When these vessels are hauled up, how are they supported; do they leave the cradle about her, or take it away?—They put in shores immediately, and relieve the cradle, which is then removed.

How do they get the cradle from under her?—The recent improvement Mr. Morton has made is such, that they have the power of supporting the vessel by shores in the usual way, with a slight degree of wedging; the vessel rests on them. The cradle then slides off, and answers for drawing another vessel on the same slip. I have never seen any practical difficulty in relieving her. In half an hour after the ship had been drawn up, the cradle was gone, and the vessel supported by shores; that is to say, the chocks and every other impediment to the workmen was removed, and the people were seen tearing off the copper, and otherwise at work fore and aft.

She was quite free?—Yes, from end to end.

If any private ship-builder wished to have full means of repairing his vessels, would it be more for his advantage to place one of these slips in his yard than to excavate a dock?

—It certainly would be vastly less expensive, and when completed the patent slip would be more efficient. I stated formerly that it would be an advantage where the rise and fall of tide is small, in consequence of not having to pump the water out; but, on the other hand, the slip would require to be carried much farther into the water than where the rise and fall is great, in order to get the vessels on the slip. In places where there occurs a great rise and fall of tide, and advantage can be taken of the tops of the tide to place the ships close to the end of the dock, there is no necessity for carrying the slip far into the water.

Mr. *George Graham*, of Harwich, Ship-builder, called in; and examined.

HAVE you one of Mr. Morton's slips?—I have; it is calculated to take up a ship of 500 tons.

Will you state to the Committee how long you have had that slip, of what service it has been to you, and your general opinion of it, and why you put it up?—I have used the slip six years, and during the first five years I took up 84 vessels of various classes; the largest was about 386 tons.

By whom was it fixed?—Mr. Morton supplied the materials, and I laid it down myself; he supplied the iron work only.

You paid for the patent right, and did it yourself?—Yes.

Will you have the goodness to state to the Committee what was the cost or the outlay to you, independently of what you gave to him?—I gave to Mr. Morton the usual patent fee of £.200, and including every other charge it cost me £.3,040; it is calculated to take up a ship of 500 tons. It may be necessary to state, that in consequence of the nature of the ground at Harwich, I was necessitated to drive two tiers of piles within four inches of each other, to carry the centre way, and a single tier to carry the side ways.

Was the entire amount of £.3,040 paid to Mr. Morton for the materials and the patent right?—The sum of £.3,040 includes every expense. Mr. Morton supplied the iron work only; the precise amount paid Mr. Morton I do not now recollect; there was a regular scale, and Mr. Morton's statement will give the price of the iron work.

You do not recollect the sum total you paid Mr. Morton?—No. In consequence of the slip at Harwich being very much exposed, it was thought the lifting of the sea would cause vessels to strike so hard upon the carriage, as to break the iron railway if it were of cast iron; I consulted Mr. Morton upon the propriety of making it of wrought iron; he entertained the same opinion as myself as to the hazard of laying it of cast iron; the experiment of substituting wrought iron bars was made, but it was found they would not bear the weight of the ship. This alteration, combined with making a secure foundation, will account for the additional expense.

It has always answered?—It has not moved in the least.

Will you state to the Committee how you have found it answer, and your general impression of its advantage?—That the Committee may be enabled to compare the improved with the old system of heaving up ships, it may be necessary that I state the expense attending the latter. We have drawn up ships of 1,000 tons and downwards, on the old principle; upon the old principle the ways were laid on two inclined planes, by timber

across, and planks laid on them on each side of the ship. [*The Witness further explained the difference of the plans, by referring to a model of the Patent Slip, calculated for Frigates, which was upon the Table.*]

What was the expense on the old plan of a ship of 500 tons?—In taking them up on the old system, there would be a great risk, and much variation in the expense, arising out of circumstances against which no human being could guard, by which the expense might be increased very considerably; in some instances more than others;—a ship of 450 tons cost £. 195, exclusive of the wear and tear of falls, and the materials to set her up with afterwards,—this was owing to various circumstances which added considerably to the expense;—a ship of 666 tons cost £. 153; taking the average of the two, £. 170.

That would be £. 170?—Yes; on Mr. Morton's principle I could heave up a ship of 500 tons for £. 3, and there is no risk whatever; if the ship is as weak as it is possible, she may be brought on without the slightest injury.

By the old way you were obliged to secure the tackles to the vessel herself?—Yes.

Therefore if there were any weakness it would injure the vessel?—Yes.

Is there any strain on vessels by the new plan?—No, none.

How would they have managed to get a vessel on the ways when there was little or no tide?—It could not be done upon the old plan; it would require two or three days to heave up a large ship.

Where there is little or no fall of tide, and close to the shore, how would a slip of this kind be laid down?—It might be carried out and laid upon piles, upon which a platform to receive the slip has been laid. I am informed this has been done in Ireland, and the slip carried out considerably below low water.

How is it carried?—A frame is made carrying the three lines of ways; the upper part being secured, the others are forced down in their places, and piles driven down to secure them.

Must not piles be driven as a foundation?—Not in the extreme part, in consequence of there being little or no weight upon that; the extreme part serves merely as a guide to the carriage.

How high from the foundation part—the keel—does the cradle come up in your slip?—The additional height is attained by placing more or less blocks, according to the ship's bottom.

Still you must have something to hold those blocks?—Yes.

What height are they from the ground?—About two feet, the under side.

Did you not say it cost you £. 500 to draw up a vessel of 1,000 tons?—Yes.

What would it cost by this mode?—I suppose, of course, if the carriage and materials were made additionally strong, it would cost about £. 12.

You need hardly be asked if you consider it a useful invention?—I think it is one of the greatest improvements we have had; it is applicable to any case, and may be used in a situation where it is impossible to have a dry dock.

Do you consider that £. 5,000 is a sufficient remuneration for the inventor of this?—I think not; he has devoted much time and much expense. I should have considered his expense considerably more than he has mentioned; he must have failed in many instances.

Knowing ship-building well as you do, and the principles on which he grants his license, do you consider any injury could accrue to the shipping of this country, if the patent were renewed?—Not at all; the advantage is so great, the sum so small, compared with the advantage. Ships are repaired at a much less expense; there is a great saving to proprietors; men perform more work in the course of the day; the hours of work are increased during the winter months; the ship derives great advantage from the circulation of air in every part; and there is also the facility of conveying materials, and observing the progress made in the work from every part of the premises.

You are aware this is put up in foreign countries?—Yes.

That is, without making any payment to Mr. Morton?—Yes.

Does not that place the ships of this country in a disadvantage as compared with the ships of a foreign country?—In foreign ports where ships are, and requiring repair, they will have it done. The amount of the patent fee I do not conceive would alter the intention of any person disposed to lay down the slip. Its advantages are so great, I cannot see any injury to the shipping interest.

Have you ever found that the rollers have been crushed?—No; I have tried mine to the full extent it was calculated to bear; neither have I found the abutments vary; mine is only a sandy foundation.

Have you found the keels of the vessels bent?—It is utterly impossible. The reason I say it cannot possibly be bent, is because she is supported not only in the centre, but also at the floor-heads, and should the purchase break, the ship cannot be injured, no part of it being fast to her.

Are you aware of the improvement Mr. Brown has made?—Last week I heard it for the first time. I do not know the principle of it; I merely heard that he had recently taken out a patent for something, but the principle I am ignorant of.

You say the keels of vessels are never injured by this invention; did you find them injured by the former mode?—There was very great risk; if a ship was weak, she would naturally yield, the weight being thrown on the midship part of the ship; if the two extremes were unsupported, that would strain the ship; if a ship's keel were broken, or if her back were broken, she would yield very considerably, under the old system.

You have considerable sea at Harwich?—Yes.

Have you ever used your slip when the sea has been running?—Yes.

Did you at those periods find it easy to bring the ship into her place in the cradle?—It is rather troublesome, but I should say not more so than on the old principle.

In the course of your experience with this, have you ever had the accident happen to you at the time you intended to bring the ship up, of missing to bring her into the cradle?—Yes, several times; in consequence of the sea running, it became hazardous; I was then obliged to take her off again, it was impossible to hold her.

It is not very easy to point her into the place you mean to bring her?—It requires nothing more than care; if the wind blows hard, it is difficult.

Do you allude more particularly to the wind or to the sea?—Of course to the sea.

Is it necessary to point her in with great nicety?—Yes.

If the ship were to get on one part only, it would strain her?—It would make her strike on one side, and the sea running from under her might cause injury to the carriage.

When you cannot point her in without that, you are obliged to desist?—Yes.

To that extent the machinery is inferior to a dock?—It will be impossible to bring her into dock under circumstances when you cannot bring her into the slip.

In no instance in which you would not fail to get her into dock, would you fail of getting her into a slip?—In no instance at Harwich; when a ship is in dock in other ports, there would be less trouble in placing her. It is these winds and sea that would cause the difficulty with me.

Generally speaking, that is a small disadvantage, that in blowing weather, or when there was much sea, she might be got into dock, when she could not be got into slip?—In some cases it would be the case, but not so in Harwich.

You say that if you were now commencing ship-building, and had a yard at Harwich without a slip at all, it would cost you nearly £.2,000 to erect a slip on the old system that would be applicable to all kinds of vessels?—Yes, with the materials for heaving up.

You consider that this would cost £.1,000 less than the other?—Yes.

Pray, during the six years you have had the slip, how many vessels have you hauled up?—Eighty-four.

What was the average cost of hauling up these vessels?—If I give the Committee a statement of the grade of prices for the various tonnage, it will suffice: under 50 tons the charge would be 15*s.*; from 50 to 100 tons, £.1; from 200 to 300 tons, £.2; from 300 to 400 tons, £.2. 10*s.*; from 400 to 500 tons, £.3.

What is the largest vessel that has been drawn up?—Nearly 400 tons, not quite.

What would it have cost on the old plan to have hauled up this vessel?—A vessel of about 90 tons would be £.17. 15*s.*; 200 tons was £.60, and the others of a larger size £.500 and £.600.

Do you apprehend there would be any difficulty in applying the power, without much friction, to larger vessels?—No; I think it might be constructed to carry almost any size.

John Farey, Esq., called in; and examined.

Did you draw the specifications for the patents for Mr. Morton and for Captain Brown?—Yes; for Mr. Morton in 1818, and for Captain Brown in 1831.

Have the goodness to state to the Committee what is the difference between the two plans?—I do not consider those two inventors to have had a common object in view. Mr. Morton's slip is for drawing up ships out of the water to repair them, as a substitute for dry docks; Captain Brown conceived a very extensive project for conveying ships over land upon horizontal stone railways; he called it a ship railway. It was necessary, in order to transfer the ships from the water to these level railways (which he intended to lay across the country) to use inclined planes, up which the ships could be drawn; and inasmuch as the ships were to be drawn up inclined planes, that portion of Captain Brown's plan resembled Mr. Morton's, who had no further object than to haul up ships for repairing or laying up. The mere fact of hauling up ships out of the water on the

dry land is not Mr. Morton's invention, but his improved mode of doing it, beyond the previous modes, is his merit.

The plan of hauling ships up inclined planes, which had been used on some very rare occasions before Mr. Morton's slip was invented, was precisely the reverse of launching a new-built ship into the water; viz. two long inclined fixed ways of timber were laid temporarily on the ground beneath the vessel, on each side of her keel, just like the ways which are prepared for launching a new ship; and in like manner a timber cradle was applied to the bottom of the vessel, fitted as nearly as could be to the curvatures of the bottom, and resting on the fixed inclined ways. This preparation being made, the ship and cradle were hauled up by purchase tackles, which were passed round the stern of the ship, and around the cradle, so as to get a secure hold of both. This method was so troublesome, laborious, expensive and uncertain, that it never was or could be used, except as an expedient to repair a stranded ship, which could not be removed into a dry dock.

Mr. Morton's mechanical slip was, in my opinion, quite a new invention at the time he took out his patent in 1818. The great feature of novelty and merit in his invention consisted in getting a complete wheel carriage underneath the bottom of the vessel, which wheel carriage has one long strait middle beam, extending beneath all the length of her keel, with blocks fitted upon it for the vessel's keel to rest upon, precisely in the same manner as the weight of a ship is supported while building. The cradle, which had been occasionally used before, was not one carriage, but two distinct parts, each part resting on one of the fixed temporary inclined ways, the two parts being fitted beneath the opposite sides of the vessel's bottom, without any connection between the two parts of the cradle, or offering any support beneath the vessel's keel. It was quite a chance how the two parts of the cradle would fit to the bottom of the vessel, to sustain it, without occasioning unequal bearings, and twisting or straining the vessel out of shape. As all vessels are quite strait at the under side of the keel, or else have some known curvature thereof, it is easy to dress the blocks, which are placed on the middle beam of Morton's carriage, to a strait line, or to the known curvature of the keel, before the ship is taken up; and owing to the structure of the slip, it is certain that there will be no deviation in the form of the carriage, when the weight of the ship comes upon it, because the carriage is borne in such a substantial manner, upon solid railways of cast iron, founded upon timber and piles, or upon stone-work, the bearing of the carriage being by means of numerous wheels or trucks of cast iron, which are adapted to run upon those cast-iron railways, whence it is quite certain that the carriage will not alter its figure by the weight of the ship. There were other accessary contrivances of concurrent importance to the complete performance of the object, such as cross bearers to the carriage, with blocks sliding along them athwartship, to be jambed in beneath the curved bottom, for the purpose of keeping the vessel in an upright position, but without bearing any material portion of weight on those blocks, for they are not jambed into their places until after the vessel has settled down to rest on her keel, the great weight being thrown on the middle railway, by the keel resting on the before-mentioned blocks along the middle beam of the carriage, which are similar to the blocks on which a vessel is built; also a very com-

plete and convenient purchase tackle, of adequate strength and power for drawing up the wheel carriage and ship on the inclined plane by men working at a capstan or at winches, with cog-wheels, and a strong chain, the chain being attached to the carriage, and not exerting any pull on the ship; also strong palls to catch into a cast-iron rack of serrated teeth, which is formed between the railways on which the wheels of the middle beam of the carriage run, which palls retain the carriage and ship from running down the inclined plane, although the palls offer no obstruction to the ascent of the carriage when it is drawn up the inclined plane. No such palls were or could be used to secure the cradle, in the former mode, from sliding down the ways; but if the tackle broke during the operation, the ship must have slipped back into the water, which can never happen in Morton's.

Do you consider that Mr. Morton's was an original invention, and did you deem it a great improvement on the old plan, wherein no ways or cradle were used?—I considered it an original invention at the time, and my attention has been frequently called to it in the last 14 years, during which time I have seen no reason to alter my opinion. The old mode of hauling up a vessel without ways or cradle, is only proper for fishing-boats; it would be destructive to treat a vessel of any size in that barbarous manner; and it is in fact impracticable, except for small vessels.

I ask you whether, if instead of this new invention of Captain Brown's, to which you have alluded, being for transporting ships over land, it had been confined to merely getting them out of the water, would you have considered his mode of doing that as an improvement on the plan of Mr. Morton?—That question involves the consideration of the details of the two plans for drawing ships up inclined planes out of the water; and I am not aware of all the details of that portion of Captain Brown's plan, because at the time I made his specification he had not made any machinery; whereas Mr. Morton has constructed many large machines with which I am well acquainted; hence, in answering the question, I should be drawing a comparison between a project which, as far as it is known to me, is not fully made out in all its details, and a reality which is in constant use.

Since the plan of Captain Brown has been brought to perfection, and his model completed, have you seen it?—No, I have not seen any model of Captain Brown's at all.

But cannot you judge from the specification?—Yes; I can judge from the specification, because I wrote it and made the drawings belonging to it; but I shall be under the necessity of comparing a project with a reality, and with that premise I will give my opinion. The great improvement that Captain Brown expected to make, was by applying loose rollers for the carriage to roll over when it ascends the inclined plane, in place of wheels turning on axles or pivots, which Mr. Morton uses. To support the carriage, the specification of Mr. Morton's patent of 1818 mentions rollers as well as wheels; and he made a set of rollers for his first slip in 1818 in lieu of wheels, but could not, on trial, make them answer with certainty and safety, and therefore has kept to the wheels ever since. I think he is right. Rollers without axles will certainly diminish the friction of rolling bodies over them; and it has been proposed, at various periods, to apply rollers in place of wheels to carriages generally, and many very expensive attempts have been

made to achieve it, in a variety of ways, but they have been almost uniformly abortive attempts. I have scarcely ever known the application of rollers to succeed in lieu of wheels for bearing great weights. The great reason is, that loose rollers without axles require two hard surfaces, one above them as well as one beneath them. It is not enough to have a hard and strait road, but there must also be a hard and strait bottom to the carriage. Another difficulty is, that a new supply of rollers is always wanted to be put before the carriage as it advances, and other rollers come out from behind the carriage; hence there must be some means of transporting the rollers which are left behind the after part of the carriage to the fore part, or else there must be a great surplus of rollers provided to furnish all parts of the road with them. Another difficulty is to keep the rollers in their places on the road-way, and to keep the carriage strait on the road-way, which is a most essential condition for hauling up a ship. The rollers should be loose and unconfined beneath the carriage and on the road-way, for if they are confined by axles or guides, a great part of their advantage in the diminution of friction will be lost; and if the rollers are laid loose on the road-way, they are always getting together in clusters, and getting awry, so as to fail where they are wanted to support the carriage. We see every day that this plan of loose rollers answers very well for the casual transportation of heavy stones and masses of iron for very short distances where men are constantly on the watch to keep the rollers strait and equidistant beneath the weight, and to apply fresh rollers in front when requisite; but for any machinery that is intended to perform an expeditious operation, and to move through considerable distances, such rollers (as far as my experience has gone) have invariably been found very inferior to wheels on axles, except where the moving carriage is required to turn round in circles like a windmill head, or a turning bridge, or a crane, because as the rollers then go round over and over the same road, they do not require fresh rollers to be shifted from the hinder part of the carriage to before it. According to any plan which I can conceive of applying rollers in lieu of wheels, with axles, to the carriage of Morton's slip, they would, in my opinion, certainly be inferior to the wheels which Mr. Morton uses, for the rollers would be under water and could not be watched, and would be most exceedingly liable to get out of place, and bear the carriage unequally, and serious accidents might happen to a ship before it was known that a bearing roller had shifted out of its proper place.

My question was, supposing Captain Brown's plan to succeed, and his invention to have been confined to getting the vessel out of the water, would it not be rather an improvement on Mr. Morton's plan than an original invention?—Captain Brown's can only be an improvement on Mr. Morton's in any case; but Mr. Morton contemplated the use of rollers in 1818, and tried them just as Captain Brown proposed to do in 1832.

Are you impressed with the conviction that Captain Brown has no means of keeping the rollers at fixed distances under the carriage, and that there is not a continuation of rollers at some distance; what do you mean by rollers being loose?—Yes; Captain Brown proposed to connect the pivots or axles of the rollers one to another by links like a chain, or like the steps of a ladder, and that was what Mr. Morton tried; but when the rollers are effectually confined from getting out of place by such means, the friction arising from such

means of confinement, will take away a great part of the advantage which appears to result from comparative experiment of their friction against the friction of wheels which move on axles or pivots. The confinement of the rollers, if effectual, causes the friction to approach very much to the friction of well-made common wheels with axles or pivots. When the latter are fairly tried, that is, when the pivots are well made, of good hard materials, polished, well greased, and tried when they are set in motion; not the friction of beginning to move, for the friction of axles or pivots is far greater at first starting from rest than the friction of continuing motion, when it is once commenced. All small experiments, such as have been stated to the Committee, are most deceptive, and when such plans are reduced to practice on a large scale, very different results are found. If you observe a lot of workmen, when transporting a heavy block of stone on loose rollers, you will see that they are obliged to watch and keep the rollers strait and equidistant, by applying their crowbars frequently. If machinery is applied to confine these rollers in their places, a great portion of the advantage which appears to arise from the experiments on unconfined rollers will be found wanting. There was another point in Captain Brown's plan, which bore more completely on the similarity to Mr. Morton's, because the purpose was similar, but extended farther; viz. for laying up ships in ordinary after repairing them. It was the addition of a transverse horizontal way across the upper end of the inclined plane, in the manner of the top part of the letter T, in order to carry a ship, sideways, out of the line of the inclined plane, to make room for others thereon; so that one drawing up machinery and inclined plane, would serve for a large establishment, for repairing and laying up many ships in ordinary, in a row, on the horizontal railway, which extends across the upper end of the inclined plane. Mr. Morton's might be used in that way, if it was advisable to do so, for a large dock-yard. I have been told, that one of Morton's slips, which has been made at Petersburgh, is provided with such an addition to it, for laying up steam-boats and lighters in the winter.

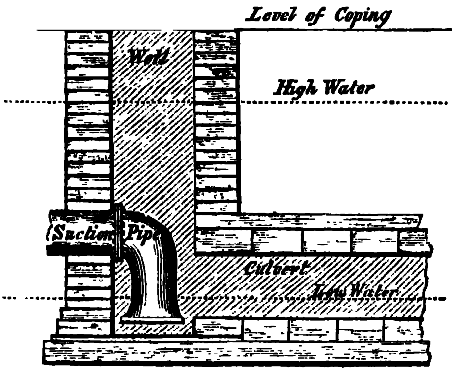
As you are well acquainted with the subject of patents, perhaps you can answer this: Captain Brown's patent being taken out now, and if, as you say, Mr. Morton could use such a cross railway with his patent slip, would that, in your opinion, be an infringement of Captain Brown's patent?—I should think it would, for it would be an improvement on all that Mr. Morton had done, and something which he did not contemplate in his invention; and if it is a new and useful addition, the inventor, Captain Brown, would have the right to it.

The patent does not bind Mr. Morton down to the plane being taken in a direct line; it might be curved at the top?—Certainly, he might do that; but my opinion that he would be infringing on Captain Brown's patent, is in reference to the difficulty of performing such a lateral transfer of ships from Morton's slip, as well as the advantage of doing so. If it requires new contrivance and machinery for the purpose of carrying Captain Brown's addition to Morton's plan into execution, then Captain Brown would have a right to the benefit of what he invented, in addition to his predecessor; but if it only required some management of the same machinery which Morton invented to transfer the ships laterally, after having drawn them up thereby, then any person would have a right to carry it into execution, if they were able to do so, in spite of any patent. Patents can only be maintained for new inventions, not mere self-evident alterations.

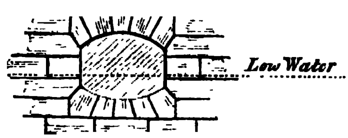
Appendix (I. 1.)

DESCRIPTION of the Pumping Apparatus and Culvert at the St. Katharine Docks, by Mr. *Thomas Rhodes.*

There are two engines, each 80-horse power, which are connected (or can be worked separately) by a line of triple cranks, which work six double-action pumps. The pumps are three feet diameter, and 4 feet 6 inches stroke, and are all connected to a horizontal suction pipe, 3 feet 6 inches diameter, bent at one end, and draw the water from a well 8 feet diameter of ashlar masonry; the bottom of this well is laid three feet below low water mark.



Section of Culvert



The culvert which communicates with the well and river is 170 feet in length, 8 feet wide, and 6 feet 6 inches high, formed of ashlar masonry, the bottom of which is laid two feet below low water of spring tides, and the water is thus conveyed from the river to the well.

A grating is fixed near the outer end, to prevent any floating body from becoming entangled and gagging the pump-valves.

The water drawn up by the pumps can be discharged either into the entrance lock or basin, separately or together, by means of sluices or valves in the interior of the pipes.

"St. Katharine Docks, 13 Dec. 1827.

"Experiments made (of the effect) with Messrs. Bolton and Watt's pumping-engines; each 80-horse power; together 160-horse power:—

"1st. Filled the entrance lock, the dimension of which is 180 feet long and 45 feet wide, (11 feet 11 inches, say,) 12 feet in depth, in 5½ minutes, with the assistance of the sluices in the lock gates.

"2d. Raised the water in the lock 8 feet in depth, with the engine, alone, in 17 minutes."

Mr. Brown, agent to Messrs. Bolton and Watt, assisted, and noted down these experiments.)

16 Dec. 1827.

Mr. Telford, accompanied by Mr. Rickman, Mr. Hall, the secretary, Mr. Hardwick, the architect, and a number of the Directors, came to witness the performance of Messrs. Bolton and Watt's pumping engine. Raised the water in the lock 12 feet high, in 6½ minutes, which gives 14,953 cubic feet per minute, equal to 417 ton per minute. This I consider was not a fair trial, as the tide being very low, there was little water in the culvert.

T. R.

Appendix (I. 2.)

INFORMATION useful to Owners, Masters, Pilots or Persons in charge of Vessels and Craft, about to enter, whilst lying in, or departing from, the St. Katharine Docks: with an Abstract of the Regulations, and a Table of the Tonnage Rates.

Under the authority of an Act passed in the tenth year of the reign of His present Majesty George IV., intituled, 'An Act for altering and amending the powers of an Act 'of the thirty-ninth year of the reign of King George III., for rendering more commo- 'dious and for better regulating the Port of London,' bye-laws have been established on the 29th of September last, which will secure to shipping passing up and down the river between Blackwall and London Bridge, (under severe penalties, to which the harbour-masters are also liable if the duty shall be neglected), a clear channel of not less than 300 feet in width.

The entrance lock of the St. Katharine Docks is 180 feet in length between the gates, and 45 feet in width. The depth of water, at the top of the tide on the sills of the entrance lock-gates, spring tides, is 28 feet; at low water 10 feet; neap tides, 24 feet at high water, and about 12 feet at low water, Trinity *datum*.

The eastern dock is open for the reception of ships and goods, and, with the western dock and basin, accommodation is now afforded for about 140 vessels, besides craft, at one time.

Upwards of 1,000 vessels have entered and departed the St. Katharine Docks during the last eighteen months, without difficulty, several of which were from 500 to 1,000 tons burthen.

Ships entering the St. Katharine Docks are permitted to retain their crews on board, which in many instances saves the owners the expense of boarding them on shore.

The following Table exhibits a scale of the rise and fall of tides, and represents the depth of water upon the sills of the lock-gates at the entrance to the St. Katharine Docks during the flood and ebb tides therein referred to.

TABLE, showing the Rise and Fall of the TIDES off ST. KATHARINE DOCKS, with the Depths on the Sills of the Outward Lock-Gates during SPRING and NEAP TIDES. The Bed of the River has been excavated in a Slope to the deepest part opposite the entrance.

SPRING TIDES.

	Depth. Ft.	Depth. In.		Depth. Ft.	Depth. In.
1st Hour after flood - -	16	–	1st Hour after high water -	24	6
*2d ditto - ditto - -	21	2	2d ditto - - ditto - -	20	10
3d ditto - ditto - -	24	–	3d ditto - - ditto - -	18	2
4th ditto - ditto - -	26	6	4th ditto - - ditto - -	15	7
5th ditto, and at high water	28	–	5th ditto - - ditto - -	13	2
			6th ditto - - ditto - -	11	3
			At low water - -	10	–

* Spring tides frequently lift 9 feet during the first hour flood.

NEAP TIDES.

	Depth. Ft.	Depth. In.		Depth. Ft.	Depth. In.
1st Hour after flood - -	13	6	1st Hour after high water -	21	11
2d ditto - ditto - -	16	10	2d ditto - - ditto - -	18	–
3d ditto - ditto - -	20	3	3d ditto - - ditto - -	16	2
4th ditto - ditto - -	22	7	4th ditto - - ditto - -	15	6
5th ditto, and at high water	24	–	5th ditto - - ditto - -	14	–
			6th ditto - - ditto - -	12	10
			At low water - -	12	–

The rise and fall of tides are subject, in a great degree, to the influence of winds and weather: upon very lofty springs, upwards of 30 feet depth of water exists, at times, at the entrance. *

* The stream generally runs up from 25 to 40 minutes after the flood-tide has made its mark.

If owners of vessels of a very large draft of water deem it advisable to employ tugs, the Steam Navigation Companies will, when required, cause such vessels to be towed from Deptford to the St. Katharine Docks, or *vice versâ*, for £. 10. 10*s*. When proceeding with the current, the most expedient course is to place the steam-boat alongside.

Vessels of a large draft of water proceeding to the St. Katharine Docks ought to break ground from Blackwall at young flood, and from Deptford before half-flood; temporary berths for ships of large draft of water may be found in the vicinity of Bell Wharf, off the Surrey Canal entrance, Hanover Hole, or at Union tier, where they may make fast, if deemed expedient, until the next flood.

Vessels and craft may be docked or undocked during the day or night, at almost all periods of the tide, and by the improved construction of the lock, may, in a few minutes, (when the water in the river is lower than in the dock) be raised 12 feet in the lock to a level with the water in the dock; an arrangement which affords great and exclusive despatch, facility and security to shipping frequenting the St. Katharine Docks, and from which pilots derive an important advantage, as they are not subjected to detention, but may leave London immediately for their stations, so as to be in readiness for another turn. Several vessels have been docked after dark within the last few months, in perfect safety. Some pilots prefer bringing ships through the Pool in moonlight nights.

Any ship which shall reach the dock-buoy is certain of being admitted the same tide, if it is desired by the captain, notwithstanding it may have ebbed. Another advantage, from the peculiar construction of the lock, particularly to large ships, is, that vessels of a great draft of water may be locked out into the stream three hours before high-water, and may thus reach Blackwall long before the flood-tide has made its mark.

A mooring-craft is stationed on the north side of the river channel to the eastward of the principal dock-buoy, to facilitate the entrance of vessels into the docks. For the convenience of shipping frequenting the docks, a blue light will be exhibited at night on board the mooring-craft.

A berth has been provided between the principal dock-buoy and the mooring-craft, where vessels of a large draft of water may wait for orders. Pilots or others in charge of any such vessel (not being laden with pitch, tar, or wood goods, which articles will be admitted only upon special agreement) may, however, enter the basin at once, and if the owners of the ship or cargo should disapprove of the discharge in the St. Katharine Docks, a charge of £.1 only will be made for docking and undocking, provided such vessel be removed from the docks within twenty-four hours.

So soon as a vessel approaches the St. Katharine Docks (unless otherwise directed by the dock-master) a strong warp must be carried out from her starboard-bow to the mooring-craft, and sheered in as near as may be to the east Dolphin-buoy, and another also carried from the larboard-bow to the capstan upon the west pier-head, by which she will be hauled in. If the wind blows strong from the south or southward of west, a stern-rope ought to made fast to the principal dock-buoy or the west Dolphin-buoy, to drop her into the entrance: whenever the ebb-tide has made, she should in the first instance be hauled close up to the principal buoy, a warp made fast from the larboard-quarter to the west Dolphin-buoy, and a rope carried out from the larboard-bow to the capstan, on the west pier-head.

A blue flag will be kept flying in the day-time on the western pier, during the period considered proper for docking.

The master, pilot or person in charge of any vessel about to enter the dock, arriving at the entrance-buoy after dark, should immediately communicate with the dock-master in attendance, so that steps may be taken for her admission.

Prior to a vessel entering, the sails should be furled, yards topped and secured, jib-booms, running-bowsprits, out-riggers and spanker-boom run in, spritsail-yard fore and aft, all boats lowered down, davids topped up, and fenders ready at the bows, anchors stowed on the forecastle, guns (if any) unloaded and run in, and gunpowder removed from on board: the vessel should also be provided with good and sufficient hawsers, ropes and tackle, to make fast, moor and remove her with safety.

A servant of the company will deliver to the person in charge of any vessel about to enter the docks, a copy of these regulations.

The docking and undocking, mooring, unmooring, moving and removing, dismantling, &c., will be entirely under the control and direction of the dock-masters, and no rope must be cast off or slackened whilst hauling in or out, without the dock-master's orders.

The security, convenience and despatch which wet docks afford to shipping, as compared with the means which exist for discharging and loading alongside the river wharfs, or in the stream, are well known. A short time ago, a vessel from the Baltic, intending to discharge at a river wharf, fell over and bilged; another broke adrift, and carried away her masts, &c.; whilst vessels unloading at places which ebb dry, generally sustain injury, and are always subject to extraordinary wear and tear.

Masters or other persons in charge of vessels or craft about to enter or depart the docks, or during the act of transporting within the same, should cause fenders to be hung over the sides, and at the bows, and must enjoin the crews to be cautious in the use of staffs or boat-hooks, so that no damage be done to the walls of the docks, lock or works.

One boat afloat only will be allowed for the use of each ship whilst in the docks, nor are sails permitted to be loose after sunset.

A copy of the manifest of every vessel entering the docks must be lodged at the Manifest-office in the Long-room at the Dock-house, within twelve hours from the time of entering the basin; it should set forth whether the vessel is fully laden or not, and denote as far as possible, the goods at hand, and, whenever it can be ascertained, what goods are to be delivered overboard, or stopped for freight, and whether the cargo is to be unloaded by the servants of the Dock Company, and whether any survey is required to be held. Whenever a survey of goods water-borne, is required, notice should be given by the master or person in charge, to the wharfinger at the quay where the vessel is stationed. The Dock Company's blank form of manifest may be obtained from the dock-master, or upon application in the Manifest-office. If the master or person in charge of such vessel or craft has reason to believe that any part of the cargo has sustained damage on board, he should notify the same upon the manifest or lighter-note.

Vessels laden with provisions will, unless otherwise ordered, be discharged at the quay of Warehouse A.

With a view to despatch in the discharge of the cargoes of vessels entering the docks, the company have authority to enter and land such goods as shall not have been entered, and the Customs Order for landing, lodged with the proper officer at the docks within forty-eight hours from the date of the ship's report.

It is desirable that the vessel's register or certificate of admeasurement should be produced to the clerk in the Manifest-office at the time of lodging the manifest, as it will obviate the necessity of doing so at the time of paying the tonnage dues.

Goods landed from on board of vessels in the docks, and lodged in the custody of the Dock Company, remain subject to freight, upon due notice, until the issue of East India Company's or Dock warrants, as the case may be. Notice to stop the goods for freight must be lodged at the Manifest-office, or at the Cargo-ledger-office, in the Long-room Dock-house.

When goods have been entered by the Company under the 10th section of the 10th Geo. IV. c. 1, the owners or master of the vessel may, for the security of the owners, lodge an order at the Manifest-office not to deliver the goods without the production of the bill of lading.

Lights and fires are only allowed on board ships or craft in the docks, during the under-mentioned periods and times: viz.

From 22d Sept. to 20th March, between 7 o'clock A.M. and 4 o'clock P.M. :
From 21st March to 21st September, between 6 o'clock morning and evening.

The dock-master has authority to grant permission for fires in cabouses, or in the fore-castle if no cabouse on deck, until 6 o'clock in the evening from Lady-day to Michelmas (inclusive), and until 5 o'clock in the evening from Michaelmas to Lady-day,—and for a candle in a lantern, and coal-fires in the cabin, until 8 o'clock, throughout the year; such permission to be subject to revocation if circumstances shall render it necessary.

A bell will be rung at the first-mentioned hours, as a notice that lights and fires are allowed to be kindled, and at four and eight o'clock for their being extinguished.

Wooden funnels to the chimneys or cabouses must be securely lined with tin, copper or iron. Smoking of pipes or cigars will not be allowed upon land within the Company's premises, nor fires or lights of any kind upon deck of any vessel whilst discharging combustibles.

Combustibles in the custody of the owners thereof, are not to be allowed to remain on the quays, wharfs or deck of any ship, lighter, barge, boat or other vessel beyond two hours after notice of removal.

No combustible matter is allowed to be melted or heated on board of vessels or craft, or on any part of the premises, within the boundary walls.

Goods are not permitted to be landed, unshipped, delivered or taken in, except at such places in the docks as shall be assigned for that purpose by the Company.

The discharge of the cargo may be effected by the servants of the Dock Company, if desired by the owners or master; but no person will be allowed to be employed in the unloading or loading of vessels within the docks, except the crews thereof (stowers on board of ships loading outwards excepted) and the servants of the Dock Company, or in any work and labour to be performed within the dock premises, whether on board or on shore, without special permission from the superintendent in writing.

If the unloading is required to be effected by the Dock Company, after the manifest is lodged, notice must be given to the superintendent or wharfinger, so soon as that mode of delivery has been determined upon.

If the vessel is not provided with proper or sufficient tackle to effect the delivery of the cargo with due despatch, machinery may be obtained for that purpose from the Dock Company upon a moderate charge; but should any unnecessary delay take place in the discharge by the crew, the Dock Company possess a power under the Dock Act to send men on board to accelerate the unloading, and to charge the expense to the owners of the vessel.

The master or mate, or some person appointed by the former or by the owners, is by law required to remain on board during the whole of the time the vessel is in the act of discharging or loading, and must certify in writing to the wharfinger whenever the final delivery inwards cannot be completed without stiffening.

When ballast is taken on board, canvas or tarpauling must be nailed to the ship's side, so as to prevent any dirt or ballast from falling into the dock.

The responsibility of the ship-owner, with respect to the cargo, continues in all cases, whilst the goods are in the vessel's hold, and also as respects any injury sustained from imperfect or careless hooking or slinging, except when the goods are landed and the discharge wholly effected by the Dock Company.

The Dock Company will in no case be responsible for goods received by lighter into a vessel, or discharged from a vessel into a lighter.

Vessels when ready for clearing will hoist their colours.

If any ship, lighter, craft or vessel shall be left in the docks or basin without any person on board, the master or other person having the command, or the owner, will be liable to a penalty.

No passengers' baggage, wearing apparel or un-customable goods, are permitted to be removed from the docks, without a pass from the warehouse-keepers or wharfingers; but captains' and seamen's baggage may be removed, upon being previously searched at the gates.

Bells must not be rung, nor fire-arms discharged, on board vessels lying in the docks.

Dirt-bins are provided at convenient places at the back of the quays, in which dirt and rubbish brought on shore from on board ship must be deposited; a penalty will be incurred for placing, causing or permitting to be placed, dirt or rubbish on any part of the Company's premises, except as aforesaid, or for throwing or letting any fall into the docks.

Caulking or scraping of ships' decks, sides or masts cannot be allowed; nor any repairs to the hulls of vessels permitted in the docks, except such as shall be allowed in writing by the dock-master.

No fire will be permitted near the place on board a vessel where carpenters or joiners shall be at work.

No persons will be allowed to remain on the quays, &c., or land from a vessel to which they belong, or pass inwards or outwards after the hour of finally closing the wicket-gate at the principal entrance in East Smithfield; the periods and times for which are as follow:—

From	21st March	to	21st May,	open at	6 A. M.,	shut at	7 P. M.
„	22d May	„	21st Aug.	„	6	„	8 „
„	22d Aug.	„	21st Sept.	„	6	„	7 „
„	22d Sept.	„	1st Nov.	„	7	„	6 „
„	2d Nov.	„	20th Feb.	„	7	„	5 „
„	21st Feb.	„	20th March	„	7	„	6 „

all inclusive.

Permission may, however, be obtained for ingress or egress, at all times, in case of illness or accident, upon application to the superintendent of the police, who resides in the dock-house. The constable, watchmen or firemen on duty will show the parties where they are to apply.

Tickets of admission (to be in force so long as the vessel shall remain in dock, during the hours before specified) for the female part of the families of masters or mates of vessels may be obtained on application at the superintendent's office any day during hours of business; such tickets must be delivered up to the dock-master on the vessel quitting the docks. Female passengers entering the dock on board ship, must, if desirous of quitting on the land side, be furnished with a note, signed by the master or person in charge of the vessel on board of which they have entered, certifying the fact; to be lodged with the gate-keeper.

No visitors admitted on Sundays except upon business.

Free access on board of vessels and craft in the docks is at all times to be allowed to the officers and servants of the Dock Company.

Tonnage dues and charges on vessels should, if possible, be paid the day previous to their quitting the docks, and a communication made by the dock-master (whenever practicable), prior to the intended departure. Accounts of charges, &c., are to be obtained at the Manifest-office, and the amount thereof must be paid to the collector; upon the production of the receipt to the clerk in such office, a ship's pass will be granted, which must be deposited with the dock-master on the vessel quitting the docks.

For the accommodation of ship-owners and despatch of business, deposit-accounts may be opened with the Company, upon application to the deposit ledger clerk, in the collector's office.

Freight-books will be supplied to ship-owners, captains or brokers, on application at the Manifest-office.

A ship's book *inwards* will be deposited, for the information of the public, in the Long-room in the Dock-house, in which will be alphabetically arranged the names of the vessels inwards, of their masters, place from whence, where stationed, and whether discharging or discharged. Also a ship's book *outwards*, which will contain particulars as to vessels loading; a copy of which is lodged, for general information, with the gate-keeper at the principal entrance in East Smithfield.

A slate will be exhibited daily at the Manifest-office, in the Long-room, Dock-house, with the names of the vessels and masters actually loading or discharging at the time, and their respective stations; also a list of light vessels lying in the dock, and where stationed.

No fees, gratuities or rewards are permitted to be taken by any officer or servant of the Dock Company, nor are they allowed to receive or partake of any refreshment from or on ship-board, on pain of immediate dismissal.

Ship-owners, masters of vessels and other persons frequenting the dock, who wish to make any complaint, should represent the circumstances to the superintendent, or, if preferred, at once to the secretary; and if any unnecessary restraints or impediments in the transacting of business exist, or if it shall appear that improvements can be made in the mode of conducting it, they are particularly solicited to represent the same, when the subject will receive immediate attention.

The Dock Company have appropriated a wharf, adjoining the lock-entrance, possessing 170 feet river frontage, for the accommodation of steam-vessels, and means are afforded for passengers to land and embark, without being subjected to the risk of boat-conveyance, as the vessels will lie alongside the wharf. Convenient waiting-rooms for passengers are constructing, and arrangements are made for landing and shipping carriages, horses, cattle, &c. Warehouse-room will also be provided for luggage, &c. Uninterrupted approaches from the river to the wharf are secured by Act of Parliament, and those on the land-side afford unexampled convenience.

Thames water, at 1*s.* per tun, will be supplied to shipping, on application to the dock-master.

A crane, capable of raising upwards of 30 tons, peculiarly adapted for marble, has been erected on the quay of the basin.

Fire-engines, including a floating one of great power, are stationed within the docks.

A fireman, constables and watchmen are upon duty during the whole of the night, and most efficacious regulations have been established for preventing conflagration.

By order of the Board,

John Hall, Secretary.

TABLE of TONNAGE RATES chargeable on VESSELS entering the ST. KATHARINE DOCKS, to discharge their CARGOES, or to load OUTWARDS; subject to such revision, from time to time, as shall be found expedient.

VESSELS INWARDS.

On Vessels laden, arriving from	*s.*	*d.*		*Privilege:*	
Any port of the United Kingdom, Isle of Man, Jersey, Guernsey, Alderney or Sark, or other European Ports outside the Baltic, between the North Cape and Ushant -	–	6	Per ton register.	Use of the docks for six weeks from the date of entrance, with liberty to load outwards, and quit the docks for repairs, and re-enter.	Rent, after expiration of privilege, one penny per ton register per week. *See* remission during absence for repairs in annexed Table.*
Any other Port - - - -	–	9			

For partial remission as to ships from Spain or Portugal laden with Wool or Cork, and ships laden with Provisions, *see* annexed Table.

Rates for discharging Cargoes to be landed by the Company.

	s.	*d.*	
First Class:			
Cargoes consisting either in the whole or in part of hogsheads or tierces of Sugar, including ship-cooperage or mending - - - - - - - - - -	1	6	Per ton register.
Second Class:			
Cargoes consisting of Sugar, in bags or chests, or other goods (not being Tallow, Hemp, Corn, Wood-Goods, Pitch, Tar, Hay or Straw) contained in casks, bales, serons, chests, cases, bags, baskets, mats, bundles or similar packages; also, Spelter or Metal in pigs, bars, rods, plates, &c.			
From the East Indies - - - - - -	–	6	Per ton register.
From any other place - - - - - -	–	9	
Third Class:			
Cargoes consisting of Hemp only, or merchandize in bulk -	1	–	
" " Tallow only - - - - - -	–	6	
Mixed cargoes of - Hemp - - - - - - -	1	3	Per ton of goods. Charge in no case to exceed the register tonnage of the vessel.
Mixed cargoes of - Tallow - - - - - - -	–	6	
Mixed cargoes of - Ashes - - - - - - -	–	6	

Provided ship-cooperage or mending shall be found necessary, in the Second or Third Class, threepence per ton register will be added to the rates for discharging; but if the owners of the vessel prefer to pay the actual expenses incurred for such cooperage or mending, they will be permitted so to do, provided notice of their determination be given at the Manifest-office, previously to her breaking bulk.

VESSELS OUTWARDS.

On Vessels having entered the Docks without Cargoes,	s. d.		*Privilege:*	
Loading for any Port of the United Kingdom,‡ Isle of Man, Jersey, Guernsey, Alderney or Sark, or other European Ports outside the Baltic, and between the North Cape and Ushant - -	– 6	Per ton register.	Use of the docks for four weeks from date of entrance.	Rent, after expiration of privilege, one penny per ton register per week. See remission of Rates in certain cases, in annexed Table.†
Any other Port - - -	– 9			

‡ Except coasters loading provisions from the quays, which are exempt from charge.

PARTIAL REMISSION OF RATES, MISCELLANEOUS CHARGES AND SPECIAL REGULATIONS.

Partial Remission of Rates:

* Vessels quitting the docks for the purpose of *bonâ fide* repairs only, and returning direct to load, upon such return will be placed in the same situation, as respects their privilege, as if they had remained in the docks.

Vessels arriving in the docks laden with butter, cheese, beef, pork, bacon or other provisions of a similar description, and entering the same more than once during the year, will be charged tonnage-rates only upon the first voyage in each year; and if the cargo shall consist in part only of such goods, the rates will be remitted upon so much thereof as shall consist of the enumerated articles. Coasters entering with provisions, or loading such goods from the premises of the Company, will be exempt from tonnage-rates.

Other vessels not fully laden at the time of entering the docks will be charged tonnage-rate only on the proportion of cargo brought in, the amount of rate to be determined by the port from whence the vessel has arrived; and if discharged by the Company, rates for unloading in addition, according to the nature of the cargo and quantity so discharged.

Vessels laden with cork or wool from Spain or Portugal will be charged only sixpence per ton register.

Vessels not having discharged in the docks, loading therein in part, will be charged tonnage-rate only on the proportion of cargo taken on board, according to the port for which she is bound.

A vessel entering the basin to wait for orders with respect to the place of discharge, if directed elsewhere, will be charged only one pound for docking and undocking, provided she quits the dock within twenty-four hours.

† Whenever a partial remission of rates takes place on export vessels, and the goods taken on board consist of less than one-half the register tonnage of the vessel, two weeks only for lying in the dock will be allowed; if the goods exceed half the register tonnage, but do not amount to a full cargo, three weeks will be allowed; if the vessel remain longer, rent to be paid at the rate of one penny per ton register, per week, for such additional time.

Special Regulations:

Vessels chiefly laden with wood-goods, pitch, tar, hay, straw, or intending to discharge the whole of their cargoes into lighters, will only be permitted to enter the docks, subject to such terms as shall be first mutually agreed upon between the owners and the Dock Company.

Miscellaneous Charges:

	s.	d.
For labourers hired of the Company, who shall work on board under the directions and responsibility of captains or owners of vessels, both or either, (which rule applies to all over-board deliveries), a charge will be made for each man per day, of -	3	6
Thames water will be supplied to vessels by the Company, upon application to the dock-masters, at a charge per tun of - - - - - - - - - - - -	1	–
For an abstract of a ship's cargo and weights thereof, for the purpose of making up freight accounts, a charge will be made of - - - - - - - - - - -	2	6

APPENDIX (K.)

REPORT of The GÖTHA CANAL; being the result of a Survey made in 1808, by *Thomas Telford*, Civil Engineer, F. R. S. L. & E.

HAVING now, agreeably to the tenor of his Majesty's instructions, in company with the Count Platen, carefully examined that district of Sweden which is bounded by the great lake Wenern on the west, and that part of the shore of the Baltic which is adjacent to Soderkoping on the east;—having considered how far it is practicable to create an artificial connection, by means of water, between the several natural lakes which now occupy a very considerable portion of this district;—and having likewise taken measures to ascertain the most advantageous mode of accomplishing this object, I shall shortly state my sentiments upon the subject.

The general importance of opening an inland navigation through this central part of Sweden, as it regards promoting the internal prosperity of the kingdom, and facilitating the communication with foreign countries, has long been so evident, that it is unnecessary for me to say much upon this part of the subject. I cannot, however, in a Report of this nature, resist observing, that although the shores of the lakes Wenern and Wettern embrace a great extent of country, composed of various soils and minerals, yet, in their present unconnected state, the productions of those countries cannot be distributed to other districts but at an inconvenience and expense of transport, which either altogether prohibits or greatly circumscribes their use. This must take place in all cases where the articles to be conveyed are of great weight and bulk, in proportion to their value. In this point of view an instance of great importance occurs in respect of lime for the purposes of agriculture. In the district through which the navigation will be carried between the lakes Wenern and Wicken, the extent of fine land capable of cultivation is great, but the lime which should serve as a manure is situated at a great distance, upon the shores of the Wenern and Wettern. The forming a more perfect communication in this central

part of the kingdom will not only effect this important means of improvement, but by opening a commodious intercourse with markets in the districts to the east and west, will encourage the exertions of the husbandmen, preserve a greater equality of price, and ensure a certain supply of the necessaries of life.

From a regular and certain supply of food, other improvements will follow as a consequence. The means of ready conveyance for raw materials and manufactured articles being created, the fabrics most natural and best fitted to the local situation and state of the country will be established, and carried to an extent which is wholly incompatible with an imperfect and obstructed mode of conveyance.

Thus much I am fully justified in advancing, not as founded upon theory, but drawn from the experience of countries where inland navigation has been extensively adopted. The various other advantages which, in a political point of view, will be derived from this inland navigation, I will not presume to mention, but leave to be explained by others better qualified for the task, and shall proceed to describe and discuss those practical operations which are more immediately connected with my profession.

In regard to this inland navigation, the general formation of the country is singularly favourable. Precisely upon its summit-level, the extensive lakes Unden and Wicken form natural reservoirs, which ensure inexhaustible supplies of water, to be conducted, with nearly an equal facility, in either an eastern or western direction. Through the general ridge of this part of the country, to the westward, a valley, whose surface is nearly on a level with the waters of the Wicken, leads to an open country, which forms one gently-inclined plane, terminating on the eastern shore of the Wenern. Eastward, from the Wicken to the Wettern, and from thence to the Baltic, near Soderkoping, there is one continuation of valley, composed either of lakes containing a sufficient depth of water for the proposed navigation, or of ground favourable for an artificial canal; therefore, generally speaking, I have not, in the course of my experience, met with so great an extent of country possessed of equal advantages, and opposing fewer obstructions to a work of this nature.

In carrying the present survey over the whole track of canal, I have found the levels taken in the years 1781–4, by Mr. Schweder, under the direction of Mr. Thunberg, to be mostly very correct, and the direction of the line of canal generally chosen with good judgment. Where, in marking out the present line, I have found it necessary to vary from the former direction, it has always apparently risen only from the former engineer not having had sufficient experience or opportunity of observing works of this nature. The reasons for these deviations will be assigned in the particular descriptions of each separate division of the canal.

There being already a navigation established from the North Sea to the Wenern, it is from the eastern shore of this lake I shall begin to describe particularly this intended navigation denominated the Götha Canal.

The point chosen for the termination of this canal, upon the shore of the Wenern, possesses many advantages; it is well protected from the west and north-west winds by

sundry islands; it is accessible from the south and north-west; the ground for anchorage, consisting of sand and clay, is good; and a sufficient depth of water for the intended navigation is found near to the shore, in a proper situation for a lock. I have, in a separate drawing, shewn the manner in which this lock should be placed and protected; also, how the canal should be connected with it.

This lock, wing-walls and pier-heads must be constructed of good masonry, made perfectly impervious to water, and the wing-walls must be continued to the adjacent rocks. From these rocks to the shore, the canal may be formed with two earthen embankments, with a puddle-wall in the middle of each. The outside of these embankments must be protected from the effects of the surges by loose stones thrown down promiscuously to form their natural slope. During the time the lock is constructing, the situation must be kept free of water by a cofferdam, constructed in the direction of the lines, which, upon the drawing, are marked yellow. This cofferdam may be joined to a reef of small rocks, near to the shore, which reef can be united and made water-tight by a slender temporary wall of masonry. When the space within this wall and the cofferdam has been cleared of water by pumps, not only the lock may be constructed, but the space on the east side of it deepened for a small harbour to admit vessels to lie afloat. After the cofferdam has been removed, a pier of a triangular form, such as in the drawing, should be constructed of rough stones; this would cover the rocks which are to the westward of the lock, and, by having a capstan erected on its extremity, would be of use in towing vessels to and from the entrance of the lock. A like advantage may be obtained by building upon a rock which lies about 150 yards to the north of the lock. In order that the entrance to the lock may be effectually protected from the winds which range along the shore from the north, it will be necessary to construct a pier with rough stones, upon the rocks and shallow water on the north side of the small bay; and if the ground on the south side of this pier is excavated a few feet, deep vessels may also lie here afloat. Stones for these rough piers may be procured, at a proportionably moderate expense, from the granite rocks which are every where along the shore.

Previous to entering upon a description of the line of canal, it is necessary to mention, as my opinion, that the depth of water in it should be determined at 10 feet, the width at the bottom level 42 feet, and generally, at the line of top-water, 82 feet; and that the banks be formed one foot and a half above the line of top-water level, the width at the line of top-water to be made to vary a little according to the nature of the soil. I am led to form this opinion from considering, that some of the lakes cannot, at any moderate expense, be made to admit of a greater depth than what is equal to ten feet of still water in a canal; and that the vessels, on account of navigating these lakes, and also the Baltic and North Sea, should be as large as the lakes will conveniently admit of. I am further of opinion, that if the navigation was to be formed upon a less scale, the intercourse would be imperfect, and that the expectations (now justly) formed would be disappointed. The district of country through which the navigation is to pass consisting either of lakes or planes of very flat and even surfaces, without being intersected by any rugged ravines but what may be avoided, is very favourable for forming a canal of tolerably large dimensions, because, in passing over such smooth planes, by proportioning the quantity of ground to

be excavated to equal only what is necessary to form the banks, the expense of this part of the work is greatly lessened, as in a narrow as well as a wider canal, the banks, raised above the natural ground, require each to be puddled; and as, in all cases, the same height of lockage is to be encountered, the mere additional width does not enhance the expense nearly so much as the advantages, in the local situation of Sweden, are increased.

Having premised thus much, I now proceed to state, that immediately above the line of the highest water of the Wenern, it is necessary to construct a lock of eight feet rise, and from thence, in order to avoid cutting a very considerable hill of rock, and also to suit the termination now chosen upon the shore, the line is carried a little distance to the southward of the former one into a small piece of meadow land, which is very suitable for a basin to accommodate vessels when waiting for a proper opportunity of passing down the locks into the Wenern. As this place, excepting where the small brook passes out, is already surrounded by a bank of considerable height, it may be formed into a proper basin at a moderate expense. Immediately on the eastern side of this basin, at the road which passes to Sjottorp, another lock of eight feet rise must be placed; from thence the line passes along several arable fields, in very favourable ground, till it enters some woody land, which is more rugged. Here it is necessary to place two locks of eight feet rise each. This raises the canal to the level of a narrow valley, consisting of marshy grass-land, intersected by several small banks of apparently loose stones. On each side of this narrow valley are rugged banks covered with woods; the marshy parts require to be drained one year before the canal is made. The same level may be continued for about one-fourth part of the length of the valley, where another lock of eight feet rise will be placed. From the top of this lock one level can be preserved, in favourable ground, to nearly the upper end of the valley, where two locks of eight feet rise each must be placed in a bank where there is firm ground for proper foundations. A little to the eastward of these locks, the canal crosses a small water-course twice, and enters a very extensive track of meadow or grass-land. It is here advisable that the water-course be prevented from crossing the line, by making a new course along the north side of the canal.

To this place the former and present lines have continued nearly in the same track, but here a considerable variation commences. Instead of leaving the flat valley, and ascending eastward of Rogstorp among small rocky hills, by nine locks at equal and considerable distances from each other, I have preferred continuing the line in the valley, and constructing ten of the remaining twelve locks adjacent to each other, upon the steep bank which reaches between the village of Haijstorp and the meadow-land immediately below the village of Rixberg. To accomplish this, the line is carried, upon a level, along some fine meadow and arable land to the south-west of Rogstorp, and from thence, bending round the point of a small rocky hill, and passing through the skirt of a wood, the line is continued, still upon the same level, and making a considerable but easy curve around the eastern side of the church village of Lyrestad; from thence, bending a little to the westward, the line reaches the bank of the river, where a road crosses to the village of Solberga, and thence, after crossing a public road, passing over some very level arable land, and

through the corner of a wood, a lock of nine feet rise must be placed nearly opposite to and a little to the eastward of Norr Quarm. Immediately after this, there must be an aqueduct of three arches of eight feet span each, placed where there is a rock in the small brook, and a small bend of this brook must be cut through, in order that the water-course may pass to and under the arches in a direct line. A little way to the south of this aqueduct, in a bank upon which there is a public road, a lock of eight feet rise must be placed. From the top of this lock, by the present plans and sections, one level is continued along the whole of the extensive meadow and marshy land to the base or skirt of the bank immediately below the village of Rixberg. By continuing this level for the whole of this distance, there will, towards the lower end, be some small embanking, and towards the upper end, the canal will be in somewhat more than full cutting. Until the consistence of this meadow-land shall have been satisfactorily proved, and the plan of the drainage fixed upon, I cannot positively determine whether it will be most advisable to keep all the locks precisely as now fixed upon the plans and sections, or to place one of them about half way down the length of the meadow; but as I expect that by draining this meadow-land the surface will subside a little, and as it is desirable to have as many of the locks as possible placed near to each other, it is probable that the present arrangement will prove to be the best. It is here proper to mention, that the whole of the northern part of these meadows may be completely drained by lowering the mill-weir of Norr Quarm, and without doing any injury to that property. The total fall from the surface of the water in the pool above the mill, to that of the water in the brook a little way below it, being 22·72 feet; and the diameter of the largest water-wheel being only ten feet.

Upon the bank which reaches from the meadow immediately below Rixberg to the village of Raijstorp, ten locks are placed in pairs, with nearly an equal distance between each pair. From the extremity of the lock, which is placed in the Wenern, to the top of the lock at Haijstorp, the distance is 25,515 yards, and the difference between the level of the water in the Wenern and that of the Wicken is 162·20 feet. In this distance and acclivity, there are eighteen locks, of eight feet rise each, one of nine feet, and one of eleven feet, making 164 feet; which gives 11·80 feet of water upon the sill of the lock in the Wenern.

From the top of the upper or twentieth lock at the village of Raijstorp, to the shore of the Wicken, being a distance of 34,830 yards, the canal is carried upon one level. The general direction of the former survey is followed; but in that survey the canal was placed in a situation which required the whole depth of ten feet being cut into the solid ground; but as the whole of this extensive district has generally a gentle declivity, in a transverse section with the line of canal, and by this means affords opportunities of choosing either a greater or smaller portion of cutting, I have chosen a line where the surface of ground is generally from three to four feet below the top-water level in the canal, by which means the ground to be excavated will be sufficient to form a substantial bank on each side of the canal, without being encumbered with much surplus; which, if the whole depth of ten feet was to be excavated, would have to be laid upon the adjacent land. By adopting this mode of lessening the quantity of ground to be excavated, lessening also the depth from

which it is to be raised, and the distance to which it is to be removed, as well as the land it would cover, it is evident that the expense of the operations of the canal which relate to earth-work will be lessened more than one-third; this mode is practised with great attention in England, and I am justified in recommending it to be adopted in Sweden, after examining, very particularly, the effects which the climate has produced in the course of more than a century upon the canal of Arboga, as well as upon works of a more recent date in the canal of Strömsholm. In this great extent of line, there are only two sections of extra cutting of any importance; one of these, being at the summit near the Wicken, cannot be avoided, but the surface of the ground at this general summit of the country is only at its greatest height 6·5 feet above the level of the water in the lake; a circumstance not paralleled in any other general summit I have before had occasion to survey. A narrow ridge between this summit and the lake, of rather greater elevation than the summit, is cut through, in order to preserve the canal in a proper direction. The other section of extra cutting is through a ridge of land near Riddarchargen; here the surface of the land rises about five feet above the top-water in the canal: the reason that this cutting is encountered is, that this ridge runs for a very considerable distance into the country, and to pass round it would create a very circuitous and unnecessarily lengthened course of canal. This western shore of the Wicken being generally flat, in order to obtain a depth of ten feet of water where the canal enters, it is necessary that the bottom of the lake be excavated, of a width equal to about twice that of the canal for a distance of about 850 yards from the shore; but the bottom of the lake here being composed of sand and clay, the necessary depth may be obtained with great facility by using proper machines. The particulars of the respective lengths and heights being carefully marked upon the several plans and sections of this western district of country, I shall refer to them for all particular points of information, which it is unnecessary to detail here in writing. I shall therefore only further observe, that in this extensive portion of canal, the nature of the ground appears to be very proper for canal making; not a single ravine of any consequence requires to be crossed. The line being carried near to the summits of the country, only a very few watercourses occur, and these, being of small size, will require aqueducts of only small dimensions. Small drains will be frequently required to conduct the water which collects on the land upon the upper side, through below the canal; the precise dimensions of those aqueducts and drains can only be determined from observations taken when the snows are melting, or during heavy and continued rains. Waste weirs should be constructed where the surplus water may be suffered to pass off without injuring the canal or the country; stop-gates must also be placed at proper distances, so that in case of any accident in the canal banks, or its being at any time found necessary to draw the water off from any particular part, they may prevent too much of this extensive level being emptied; between each pair of stop-gates there must be let-offs, and these should always be placed near to some natural watercourse or general drain. Small wharfs, and places where vessels can turn round, should be made in places best fitted for the general intercourse of the country: all these will best be determined when the engineers are employed in marking out the canal for the workmen to execute.

Having passed from the western to the eastern side of the summit, Lake Wicken, in descending towards its eastern extremity a very long peninsula interferes, round which

the present navigation of this part of the lake is circuitous and tedious, not only from its great distance, but the complete change of direction which takes place; for the wind which is favourable for passing along one side, is unavoidably unfavourable for navigating the other. It is fortunate that the neck of land which joins this peninsula to the main land is only 411 yards in breadth, and that the surface of the ground, at the highest point here, is only 6·8 feet above the level of the lake, that the water is sufficiently deep very near to each other, and that the direction is also suitable; this passage may therefore be effectually improved by cutting a canal through the neck of land, and as it will on an average save one day's navigation, it is of sufficient importance to be executed.

Immediately to the eastward of this place, the lake is contracted into the width of a common watercourse, which is rapid, shallow, and interrupted by small islands and large stones. Below this place, the lake again widens a little, and is preserved of a sufficient depth by the iron-works at Forsvick. Between the level of the water in the Wicken and that of the Boren below Forsvick, there is a fall of ten feet. Here it will be necessary to form a canal on the southern side of the before-mentioned rapid, and carry it down until it reaches the lake below the shallows and small islands; here the south-eastern extremity of the lake being of sufficient depth and well protected may be entered with propriety; and from near to the south side a cut must be carried down the marshy land, which is a little way to the south of the iron-works, until it enters a small bay of the Boren, which is protected by an island. As near to the junction of the canal with this lake as a proper foundation can be found, a lock of eleven feet rise must be placed. A separate plan and section will give a distinct idea of the works necessary between the western side of the peninsula and the entrance of the Boren.

Where the water passes from the Boren into the great Lake Wettern, the passage is at present circuitous, shallow and composed of loose sand, which shifts as the eastern or western winds are most prevalent. I do not think it practicable to render this passage commodious and certain; I therefore consider it necessary that a cut be made across a piece of land which lies upon the north side of the present entrance; this cut must be extended into a proper depth of water at each extremity, leaving the present watercourse uninterrupted. Opposite the eastern extremity of this cut, if an embankment of rough stones is formed across a shallow which lies between two islands, an excellent small harbour will be formed; a convenience which will be found of importance, not only to the navigation, but the adjacent country.

Having passed over the great Lake Wettern, a sufficient depth of water continues to within a short distance of the shore, on the north side of the river at Motala; here a cut must be commenced and carried nearly parallel with the course of the river. Notwithstanding that the most advantageous ground is chosen, there is unavoidably a considerable quantity of extra cutting. The nature of the ground, however, appears to be favourable; towards the Boren, the line passes along sloping ground, and the locks must be all placed adjoining each other, a little way to the north of where the river discharges itself into the lake. The length of the canal, from where it leaves the Wettern until it enters the Lake Boren, is 6,619 yards; the fall is 51·77 feet; and there are six locks of nine feet rise each. Here due consideration will be required to preserve a proper communication with

the mills which are upon the river, without incommoding the navigation. The plan and section made of this part of the canal will show its precise situation, as well as that of the locks. In this portion there is little deviation from the former survey. I have carried the canal altogether clear of the river; the reason of doing this is to avoid the current of the stream, its soft marshy banks, and the bar or shallow formed at its entrance into the lake.

Passing to the eastern end of the Lake Boren at Husby, for nearly the same reasons as have just been assigned, instead of entering a part of the river, as in the former survey, I have marked out the line of canal to depart immediately from the lake on the south side of the river; then, after crossing the public road, the line is carried down to the proper level, and along a country very suitable for the formation of a canal. The general track of the former survey is followed; a somewhat lower level, wherever the ground will admit, is chosen, on purpose to lessen the quantity of excavation; with the exception of a very few instances of some extra cutting to avoid quick turnings, or inconvenient circuity, this can be accomplished more perfectly than is frequently to be met with in so great an extent of country. The small lake of Norrby, being unfit for navigation, is avoided, and the same level is continued from the Boren to within a small distance of the Roxen. Here, instead of passing down into and making use of a part of the river, as in the former survey, I have continued the level, bending southward towards the church Wretakloster, on the north side of which I have descended, by fifteen locks of nine feet fall each, to the bank of the Roxen, at a point about 2,100 yards south from the mouth of the river, where deep water approaches near to the shore, without the reach of the mud brought down by the river, and where good foundations for locks can be had. From where the canal leaves the Boren to where it enters the Roxen, the distance is 37,265 yards, and the fall is 134·49 feet.

At the eastern extremity of the Roxen at Norrholm the river turns to the northward, but a valley, the surface of the lowest part of which is very little above the level of the Roxen, continues to pass nearly directly eastward. In the bottom of this valley, for the distance of about 1,500 yards from the lake, there is now a canal said to have been made by a Bishop Brask; this canal is already, in most places, of a sufficient depth, and by having the shallow parts made a little deeper, and some small bendings cut off, may be used for the general navigation until it begins to bend too much to the southward. Here a new cut must be commenced and continued along the bottom of the valley, which for a considerable way is marshy and covered with wood. The line is carried along the north side of the valley, until its descent requires one lock of eight feet fall; then, continuing still along the north side in very favourable ground, the canal is marked out to enter the Lake Asplangen by two locks of six feet five inches each, pointing in a direction to where water of a proper depth can be most conveniently obtained. The shore is here flat, so that the mud must be excavated to a considerable distance, as may be seen by the plan and section. In this cut no further deviation is made from the line laid down in the former survey than what is necessary to find a proper level to render the excavation as small as possible. The distance between these two lakes is 9,806 yards, and the fall 20 feet. It

will facilitate the making of the canal, if the marshy land upon the summit is drained one year before the canal is begun at that place.

At the eastern extremity of the Asplangen, although the water is discharged in a southern direction, yet a valley, whose surface is very little higher than the level of the lake, still continues to pass, nearly direct to the eastward, and in this valley it is most advisable to carry the canal. The cut should commence at the north-east corner of the lake, and, after crossing a public road, pass along a large extent of level marshy land to the southern side of the valley; from thence the line must be continued in a winding direction between some small rocky hills, along the course of a small brook, until it reaches the road which passes from Linkoping to Soderkoping. It here follows the course of the small brook, for a considerable way, immediately along the north side of this road. When the course of the brook falls below the level of the canal, I have found it advisable to deviate very considerably from the former survey; this is done in order to avoid crossing the brook twice, after its bed is sunk into deep ravines; the level is also, by this means, prolonged, and the locks are brought nearer together. This change is effected by continuing the line along the north side of the valley in very favourable ground, until it reaches the summit of a steep bank, a little to the south-west of Marichoff; here the locks are placed in a direction which passes a little to the south of the same place, and the line from thence continues, with locks occasionally, as the general declivity requires, to near the base of the rocky promontory which is immediately on the north side of Soderkoping. After passing along the northern skirt of that town, the canal is carried still along the northern side of the valley, past a manufactory of tiles, and across a very extensive meadow, to the base of a promontory which faces the Baltic Ocean opposite to the mouth of the river, and bending a little to the north-east. I have marked out the situation and direction in which the last or sea-lock should be placed in order most conveniently to obtain a proper depth of water, have its entrance most effectually protected, and be connected with advantage to a basin on a level with the canal. The plans and sections of this district will show the manner in which the locks are distributed, and the particular fall of each; also how a basin, wharf and docks for repairing ships may be formed at Soderkoping; but it will be advisable that the two locks next to the Baltic be formed of dimensions sufficiently large to admit sea-vessels of at least thirty feet breadth of beam, when unloaded, to come up to these docks. The distance between the eastern extremity of the Lake Asplangen, and that point of the shore of the Baltic where the canal is terminated, is 27,422 yards, and the fall is 89 feet.

In the former survey the lower part of the river is made use of for the general navigation, but I have here, as in the case of the other rivers, purposely avoided it, on account of its current, marshy shores, and the bar or shallow formed at its discharge into the Baltic, partly by the mud brought down by the river, and partly by the effects of the Baltic waters when agitated by strong easterly winds.

The waste weirs, stop-gates, let-offs, aqueducts, drains, wharfs and turning places, are regulated by the same principles and plan of arrangement with those on the western side of the summit, and must be finally determined by the engineers when the precise line of canal is marked out to be executed.

The extensive track of marshy land at the eastern extremity of the Asplangen would be rendered more fit to receive a canal, if it was effectually drained.

I have already, in describing the several districts of country, mentioned, that the shape and quality of the ground are uncommonly favourable for canal work. I have now to add, that in all the situations in which locks are placed, granite rocks are in the immediate vicinity; this is an important object, not only in avoiding the expense of transport, but in diminishing the trouble and expense of inspection, and at all times ensuring a regular and certain supply of materials of proper shape and dimensions, which is not to be accomplished when the quarries are at a great distance from the works; and I must here beg particularly to observe, that it is well-chosen granite only that should be employed in all the external surfaces of the masonry which are exposed to the water, or the effects of heat and cold; stones that are laminated, or which consist of a mixture of harder and softer substances, such as most kinds of sandstone and limestone, are unfit for water-works in this climate. Next to good stones, mortar deserves the most serious consideration; neither the fit, quality and shape of the stones, nor their proper distribution in the masonry, will ensure durability to water-works, unless the quality and preparation of the lime and sand is perfectly suited to the purpose. The greatest pains must, therefore, be taken to discover, by correct experiments, the lime which, when used in mortar, will harden under water. In order that this may be fully proved, the different limestones of the country must be burnt in considerable quantities together, and with great attention; they must be slaked with as little water as will make them fall into a dry powder, and in this state, must, if pure, be mixed with three times the quantity, in measure, of clean, sharp or angular sand; they must be worked by much labour, and as little water as possible, into a pliable mortar, and used while fresh made up. By repeated trials, exposed in situations similar with those of the locks, the fittest sort will be ascertained, and a perseverance of faithful inspection during the execution of the works will ensure their durability.

It is a fortunate circumstance that immediately upon the shores of the great lakes Wenern and Wettern, there are inexhaustible quantities of limestone; amongst those it is probable that a kind proper for water-works will be found, and which may be transported by water to the points of land nearest to where the locks are to be constructed. When the most proper strata have been ascertained, it will be prudent to execute those portions of the canal first which will best facilitate the conveyance of lime to the more distant works.

Singular as the advantages are which Sweden enjoys with regard to water, it is absolutely necessary that the most perfect regulations be established, and the strictest attention be paid to the economy of it; otherwise, the navigations and all other operations which depend upon it will be rendered defective. That the advantages nature has afforded may be fully enjoyed, attention must first be paid to those lakes which are situated upon or near to the summits of the country; accurate charts of all of them ought to be made, showing the depth of water they contain, and the inclination of the ground which forms their shores; where the water issues from them, weirs with proper indexes should be

constructed in the river courses and regulating locks in the canal, by which the height of their surfaces should be regulated; sections of the courses of the rivers should be taken from these upper lakes to those which are below them, showing their relative levels, and where the falls are situated. It is necessary also to have sections made across the valleys near to the outlets, discharges and falls of the rivers; these should be accompanied by as accurate an account of the nature of the soils and sub-stratums as can be accomplished at a moderate expense. Diurnal journals or registers should be kept of the fluctuations of the rivers and lakes, and the direction and force of the winds. These data would afford complete information of all the material circumstances necessary for forming proper regulations. These general regulations would preserve much valuable land upon the shores of the extensive lakes from being overflowed, and prevent all unnecessary waste of water by fabrics situated at the different falls. To preserve the property of these fabrics equally valuable, and at the same time enable the public to derive the full benefits of the water, it is necessary that the machinery be constructed upon the most improved principles the nature of the operation is capable of. By this means, the same fall, with a much smaller portion of water, or the same quantity of water, with a much less fall, will perform a greater quantity of work than at present; and the surplus water or fall may be employed for other useful purposes. In more remote times, Egypt and China, and of a later date, Italy, have deemed this subject worthy of public attention and general regulations, and have derived most extensive and important advantages from them. England, although now fully aware of what is necessary, has suffered too many partial projects to be executed, and has, by this neglect, lost many very essential benefits which would have arisen from a general arrangement. While so many great opportunities are offered in Sweden, I presume thus particularly to mention the subject as highly deserving his Majesty's attention, as the father of his people and the guardian of their prosperity.

What I have here mentioned as applicable to Sweden in general, is particularly so to the district through which the navigation passes. The comparatively small lake Unden, the surface of which is situated ninety feet above the summit of the canal, is a striking instance of what may and ought to be done, and is alone sufficient for the purposes of the canal. Excepting at a small point near its outlet, the shores are steep, and the valley, immediately at its outlet, narrow. The area of the surface of the lake, by the survey and measurements of Lieutenant C. G. Forssell, =262,265,000 Swedish square yards, of four feet each. If, by means of a small embankment and regulating weir, a portion of the water, upon the melting of snows, or after heavy and continued rains, was prevented from running to waste, and the surface of the lake preserved one Swedish yard above what it would, at such times, immediately fall to, and if the outlet was sunk only one Swedish yard below its present bottom, then the extra quantity under the command of the regulating weir would equal 19,427,037 cubic fathoms, which might be allowed to flow out gradually, in addition to the usual quantity. That one-fourth part of this quantity would be sufficient for the purposes of the navigation will be evident from considering that $\frac{19427037}{4} = 4{,}856{,}759$; that a lock $120 \times 25 \times 9$ feet $= 125$ cubic fathoms; admitting the navigation to be worked 200 days annually, that the evaporation and leakage consumes

one-half of the whole quantity of water, and that the remainder is divided equally for the purposes on the eastern and western sides of the summit, then $\frac{4856759}{125 \times 200} = \frac{194}{4} = 48 \cdot 5$ locks-full each day, or = 97,000 locks-full annually. But the evaporation and leakage will not, if the works are properly constructed and preserved, consume one-half of the whole quantity of water. The quantity of water in each lock-full will be lessened by the space the vessel occupies; the canal will derive aid from occasional rains, and the lake or reservoir will be more than once annually raised to the requisite height. From all these circumstances, I consider that I am justified in concluding, that a reservoir capable of containing 4,856,759 cubical fathoms of water, will, if properly managed, be an ample provision for this navigation. In the proposed reservoir of the lake Unden, of two Swedish yards, or four feet of water, there therefore remains 19,427,037 — 4,856,759 = 14,570,278 cubic fathoms, to be applied in any situation on the eastern or western side of the summit, where the most useful purposes can be effected by it. But twice that quantity may be obtained by raising the embankment and weir, and sinking the outlet, to obtain the command of four Swedish yards, or eight feet; and this, in the case of the Unden, may very easily be accomplished.

If by the due management of this comparatively small lake so much can be obtained, it follows that proportionally more may be acquired by a similar management of those which are of larger extent; and that, besides preserving the same powers to the fabrics now established, a great quantity may be distributed in other quarters for other equally useful purposes; and that thereby just so much will be added to the sum total of national advantages; and that, in this view, the outlets of the Wettern, Boren and Roxen require to be regulated with the utmost attention. Besides the command which is by this means obtained over a great quantity of water, in a country where the falls are abundant, these regulating weirs are absolutely necessary to ensure a proper depth in those levels of the canal which are next to the outlets of the lakes, and also to furnish a supply of water for the lockage; the regulating locks which must be constructed near to the outlets of the lakes being only on purpose to prevent the rise of water in the lakes, above the lowest summer state, from overflowing the banks of the canal, and injuring the works and adjacent country.

Although not situated immediately upon the line of this canal, yet very nearly connected with it, the lake Ömsiön lies so near to the level to which the locks descend from the village of Haijtorp to the marshy land called Fredsberg Moss, it became necessary for me to examine the comparative levels, and the nature of the land at each end of it. The distance from the south end to the river Tidan, at Skalkarike, is about three-quarters of a Swedish mile, and the fall from the surface of the lake to that of the river, at that place, is 25·3 feet; the whole of this distance is marshy land, and of a considerable breadth. From the north end of the lake to the termination of the lockage upon Fredsberg Moss is about half a Swedish mile, and consists also of marshy land. The surface of the land adjacent to this north end is very little above the surface of the water in the lake, and very soon declines to the north; the lake, therefore, lies very nearly upon the summit of this valley. The lake itself is rather more than three-quarters of a Swedish mile in length, and

somewhat above a quarter at its greatest breadth. From the comparative levels and quality of the ground, it appears that the surface of this lake may be lowered, and the land at each end of it very effectually drained. The facility with which this may be accomplished, and the great extent of valuable land which would be gained, renders it an object of importance; and what enhances its value is, that a navigation might be carried from the canal upon that level at which the surface of the lake and drains are determined. This would prove an inducement for the carriage of lime as a manure to improve the newly-drained land, and thus become of mutual advantage to the canal and agriculturist, and of consequence to the public at large. This improvement may either be combined with the canal, or undertaken as a separate project; but in either point of view, it is of importance to have the plan determined, and the works executed, at the same time with those of the canal.

It being only necessary, in the present stage of the business, to mark out the middle line of the canal, the quantity of land which will be required cannot now be precisely ascertained; and as soils whose qualities vary, require different slopes, and as during the execution of the work, the discovery of difficult and unfit ground may require small deviations from the line now marked out, it will be prudent to appropriate 100 Swedish yards on each side of the middle line which is now marked out; this will admit of the before-mentioned deviations, as well as afford room for disposing of the earth which will arise from the excavations in extra cuttings. The land which is not required for those purposes will be useful for maintaining horses for hauling the vessels along the canal, which, for some years after the navigation has been opened, it is probable that the canal directors, in the same manner as the Duke of Bridgwater on the first introduction of canal navigation in England, will find it necessary to have performed under their own management; space will likewise by this means be furnished for placing small houses and gardens for the accommodation of the persons employed in taking care of the locks and canal banks.

As the making the canal will lead to a new arrangement of fences in the adjacent land, it becomes advisable, when the canal is laid out, to provide an ample portion of land to answer every purpose connected therewith. In cases where this has been neglected at the commencement of the works, much trouble and inconvenience has always attended the acquiring it afterwards.

Having made a careful survey of those districts of country through which the navigation is to pass, and made out correct plans and sections, shewing the precise levels of every part of the ground, also the general situation and forms of the several works which it is necessary to construct; having described each division in the order in which the survey and plans were made, and explained the data upon which the precise line of canal has been determined; having likewise made some general observations respecting the nature and application of the materials of which the masonry ought to be composed, as well as upon the economy of water; and having in every part of the country through which the canal is to pass marked the track by pits which cannot easily be mistaken; I conceive that I have now executed the service required by his Majesty's

instructions, and excepting an estimate of the expense, have done all that is required of an engineer in a general survey and report of a work of this nature.

With regard to an estimate of the expense, not having from experience any accurate knowledge of the value of labour in Sweden, I can only undertake to furnish calculations of the quantities in each species of work, leaving the prices to be affixed by those whom local knowledge has better qualified for the task; but as, through this great extent of line and variety of works, to arrange the calculations properly will require more time and attention than what, after my hasty departure and long absence from England, the state of my engagements in that country will admit of, I must therefore embrace the opportunity of a conveyance to Leith, which now offers, and take as early an opportunity as circumstances will admit to transmit these calculations to the Count Platen.

Previous to commencing any practical operations, it will be of importance to have drawings, showing in detail the particular forms and dimensions of the several works which by experience have been found best calculated for obtaining security and convenience at the least possible expense; these can also be transmitted from England.

It would greatly facilitate the operations of the workmen, and tend very considerably to lessen the total expense of the undertaking, if tools similar to those used in England were adopted in Sweden. The importance of this is more than can be easily conceived, excepting by those who have been in the habit of attending to practical operations. The minutiæ of these forms cannot be perfectly conveyed either by means of words or drawings; I therefore recommend the purchasing them in England.

I cannot conclude this report without stating, that it is only from the unremitting exertions of the Count Platen that I have been enabled to carry the survey and plans to the present extent in so short a time, and at so advanced a season of the year.

I have here annexed an abstract of the different distances and levels, so that they may be conveniently seen under one view.

EXTENT of the NAVIGATION from *Gotheborg* to the *Baltic* near to *Soderkoping*.

PARTICULAR DISTRICTS.	Present Navigation.		Lakes.		Cutting in Water.	Cutting in Ground.
	Miles.	Yards.	Miles.	Yards.	Yards.	Yards.
From Gotheborg to Wenernsborg -	7	11,250				
From - ditto across the Wenern to the entrance of the Canal - -	- -	-	10	12,000		
Lock and embankment at the shore -	- -	-	- -	-	325	
From the shore of the Wenern to the shore of the Wicken - - -	- -	-	- -	-	- -	60,020
Cutting from the shore into ten feet water	- -	-	- -	-	850	
From ditto across the Wicken to Edet	- -	-	1	15,120		

PARTICULAR DISTRICTS.	Present Navigation.		Lakes.		Cutting in Water.	Cutting in Ground.
	Miles.	Yards.	Miles.	Yards.	Yards.	Yards.
Cutting from ten feet water to the shore - - - - - -	- -	-	- -	-	230	
Cutting across the neck of land at Edet	- -	-	- -	-	- -	471
Cutting into ten feet water - - -	- -	-	- -	-	117	
From ditto across the lake to entrance of the Rapids - - - -	- -	-	–	920		
Cutting along the side of Rapids -	- -	-	- -	-	- -	890
In the Mill Pool - - - - -	- -	-	–	180		
Cutting from Mill Pool to the Boren -	- -	-	- -	-	- -	667
Cutting into ten feet water - -	- -	-	- -	-	95	
From ditto along the lake to near east end - - - - - - -	- -	-	–	12,000		
Cutting across the neck of land between Boren and Wettern into ten feet water at each end - - - -	- -	-	- -	-	- -	760
From ditto across the Wettern to near Motala - - - - - - -	- -	-	3	–		
Cutting at the shore from ten feet water	- -	-	- -	-	280	
From the shore of Wettern to the shore of Boren - - - - - -	- -	-	- -	-	- -	6,619
Cutting into ten feet water - -	- -	-	- -	-	250	
From ditto along the Boren - -	- -	-	1	–		
Cutting from ten feet water at east end of Boren - - - - -	- -	-	- -	-	310	
From the shore of the Boren to the Roxen - - - - - - -	- -	-	- -	-	- -	37,265 ½
Cutting into ten feet water - -	- -	-	- -	-	155	
From ditto along the Roxen - -	- -	-	2	6,750		
Along the Canal of Bishop Brask -	- -	-	–	1,200		
From ditto to Asplangen - - -	- -	-	- -	-	- -	9,806
Cutting into ten feet water - -	- -	-	- -	-	700	
From ditto along the Asplangen -	- -	-	–	8,400		
Cutting from ten feet water to shore -	- -	-	- -	-	62	
From ditto to the shore of the Baltic near to Soderkoping - - -	- -	-	- -	-	- -	27,422
Cutting into ten feet water - -	- -	-	- -	-	240	
TOTALS - -	7	11,250	20	2,970	3,614	143,920 ½

ABSTRACT.

	Swedish Measure.		English Measure.	
	Miles.	Yards.	Miles.	Feet.
Extent of the present navigation - - -	7	11,250	50	3,266
Ditto of lakes having sufficient depth of water - - - - - - - -	20	2,970	133	4,564
Ditto of cutting at the shores of the lakes -	–	3,614	–	7,047
Ditto of cutting Canal along dry ground -	8	–	53	410
TOTAL extent of navigation between Gotheborg and the Baltic near Soderkoping - - - -	35	17,834	238	4,868

N. B.—All the distances are taken in Swedish measure, of which two feet make a yard, and 18,000 yards one mile.

LEVELS.

PARTICULAR DISTRICTS.	Rise.	Fall.	Difference.
From the surface of the sea at Gotheborg, to the surface of the Wenern at Wenernsborg -	144·90		
From the surface of the Wenern at the commencement of the Canal, to the surface of the Wicken where the Canal enters it, as it was found on the 9th August 1808 - - -	162·20		
From the surface of the Wicken to that of the Boren - - - - - - - - -	- - -	10·00	
From the Wettern to the Boren - - -	- - -	51·77	
From the Boren to the Roxen - - - -	- - -	134·49	
From the Roxen to the Asplangen - - -	- - -	20·00	
From the Asplangen to the surface of the Baltic near to Soderkoping, as it was found on the 29th August 1808 - - - - - -	- - -	89·00	
TOTALS - - -	307·10	305·26	1·84

N. B.—The levels between the Wenern and the Baltic were taken in Swedish feet, decimally divided; between the 8th to the 30th of August 1808 (both days exclusive.)

September 1808.

APPENDIX (L. 1.)

QUERIES addressed to the HIGHLAND SOCIETY, by Mr. *Telford.*

1st. DOES it consist with your knowledge, that the progress of improvement in the northern parts of Scotland is much retarded by the want of roads and bridges; if so, what lines would tend most effectually to open the country and promote the public good?

2d. Does the valley which passes through the north of Scotland, from the Murray Firth on the east to Loch Eil, and the Linnhe Loch on the west, appear to you to be well calculated for an inland navigation, if formed of a size sufficient to admit of large trading vessels and frigates?—(I have, for the sake of distinction, named this navigation "The Caledonian Canal.")

3d. Would this navigation, by opening a ready and safe communication from one side of the island to the other, prove the means of promoting the extension of the fisheries, and of throwing the industry and intelligence of the fishers, who reside on the east coast, upon the extensive fishing grounds along the west coast?

4th. Would the undertaking these public works at the present time, by affording employment to the people, giving them habits of industry, and furnishing them with capital, tend to check the spirit of emigration which now prevails; and, connected with the powers which would be furnished by using the water which flows down each extremity of the valley from the extensive lochs, prove the means of laying the certain foundation of future employment?

5th. If the executing these roads and bridges would prove the means of employing the people, improving the agricultural state of the country, and of extending the fisheries, the nation would evidently derive an increase of revenue and power, and the land-owners through whose estates the lines of roads passed, and indeed the whole of the adjoining districts of country, would enjoy improved cultivation and pasturage, increased incomes, and all the blessings which are derived from a facility of intercourse: is it not therefore the interest of the land-owners to unite with Government in executing these plans; and should not the memorials and propositions to this purpose originate with the land-owners, and be transmitted by them to the Lords of the Treasury, who will, by comparing the memorials with the information contained in the surveys made by their directions, judge how far the public aid can be with propriety extended?

6th. If the opening of the Caledonian Canal, upon the scale I have proposed, would prove the means of facilitating the intercourse from the west of England and Scotland, and the whole of Ireland, with the northern parts of Europe, and likewise from the east side of Great Britain to America and the West Indies; is it not just and reasonable that

the commercial interests should be united with the efforts of Government in carrying the same into effect?

ADDITIONAL QUERY.

7th. In my last I neglected to state, that in order to enable the Highland proprietors to contribute, without inconvenience to themselves, a moiety of the expense of making the roads and bridges necessary for the improvement of that part of the country, they might be empowered by an Act of Parliament to sell land to that amount. This is reasonable, because the price would be applied to improve the remainder of the entailed estates, which would by this means be much improved in value, though somewhat diminished in extent.

REPORT of a SUB-COMMITTEE of the DIRECTORS of the HIGHLAND SOCIETY of *Scotland*, on consideration of a Letter from Mr. *Telford* (Engineer) to *Henry Mackenzie*, Esq., one of the Directors of the Society, made to and approved of by the General Committee of Directors of the said Society, 10th December 1802; the Right honourable Lord Macdonald (one of the Vice-Presidents in office) in the Chair.

THE Committee having fully considered Mr. Telford's questions addressed to Mr. Mackenzie, one of the Society's directors:—

In answer to the first, they are persuaded that even the lines of communication, by means of military roads in some parts of the Highlands, have been productive of benefit to the country, though the motives which gave rise to their formation having no relation to objects of commerce and industry, the advantages derived from them are very imperfect. The Committee accordingly have no hesitation in declaring it to be their fixed opinion, that the want of further roads and communications in the Highlands has hitherto proved the greatest obstacle to the introduction of useful industry there, and that every attempt for that purpose must fail, until regular and easy communication is afforded from one part of the country to another, and more especially from the remote points, where there is the best field for useful exertion, to the present seats of capital and industry. With regard to what lines would tend most effectually to open the country, and promote the public good, the Committee humbly report their opinion as follows:—

The Highlands, as to this question, may be divided into three districts:—1st. Comprehending the west coasts of Argyle and Inverness-shire, as connected with each other; the second, including the county of Ross and a part of the county of Inverness; and the third, or northern district, comprising the shires of Sutherland and Caithness.

In the first of these districts the utmost benefit would arise from drawing a direct line of communication from the west side of the Firth of Clyde, nearly opposite Greenock, to the bay of Strachur, upon Loch Fyne, from whence there is already an excellent and well-

conducted road to Fort William: from this point, the road may be easily continued by Loch-Eil side to Loch-na-Gaul, through Arisaig into Morer. Such a communication would tend very greatly to the success of the fisheries in the islands of Egg, Rum, Cana, Muck, Barra and South Uist; all of which possess numerous lochs and fishing banks in and around them. The greatest advantages would arise from approximating these various fisheries and extensive coasts to the Firth of Clyde, where the fishing capital is at present almost exclusively resident. It is evident that nothing can more discourage the employment of that capital, in those parts, than the difficulty of approach, amounting almost to inaccessibility, which renders the communication of intelligence always slow and even often precarious.

In the northern district the lines of communication would, from the nature of the thing, be drawn to a different point. A central point at the south of that district is found at or near Invershin, to the place where the Firth of Dornoch is navigable, and where a bridge can easily be thrown over, and from whence a direct and short communication could be made to Dingwall and Inverness. From this point several advantageous lines of road could be made: one stretching by the banks of Loch Shin through part of Assint to Kylescow, another by the Kirk of Lairg to the head of Loch Loxford, and a third from the Kirk of Lairg by the west of Lochnaver to Tongue. Another road, again, would connect together the western and eastern extremities of this northern coast of Scotland, proceeding from Loch Eriboll (at which place there is one of the finest harbours in the kingdom), by Tongue, Farr and Thurso, to Honna on the east. From this point, where there is a ferry to Orkney, the road would return to Wick, and from thence along the east coasts of Sutherland and Caithness, crossing the river Fleet by a bridge to avoid the little ferry, till it terminated at Invershin. Such lines as the above would open the whole of these countries to all the trading capital of Inverness, and the east coast of Scotland, as well as by the way of Fort William, to that of the Clyde; and it is well known, that all the way from the vicinity of Kylescow round to Wick, the fishing grounds are abundant and excellent.

As to the middle division, the Committee would humbly suggest the utility of certain lines of intersection from east to west; one of these ought to be from the great military road between Fort William and Inverness in a western direction, such as may best afford an easy intercourse between both these places and the islands of Skye, Harries and North Uist, as well as Loch Hourn, Loch Duich, and the other valuable fishing lochs in that vicinity. A second will lead from Contin (which has already a good road to Dingwall) by the south side of Loch Garve, and the head of Loch Lickart to Achnashen, and from thence in one branch to Loch Carron, and in another to Pollew. From one or other of these branches, a road of important benefit might be drawn to Loch Torridon, a third road will extend from the port of Ullapool, in Loch Broom, to Invershin, at the head of the Firth of Dornoch.

When the lines of road now mentioned are completed, the course of post will become rapid and regular. From the neighbourhood of Skye to Greenock, the mail would be

conveyed in three days, while from Invershin to Edinburgh by Aberdeen, or to Greenock, by Inverness and Fort William, it would be conveyed at furthest in four, and thus the most remote points of the Highlands would be brought within five days course of post, at the utmost, of Edinburgh and the Firth of Clyde. It may suffice for contrasting such a situation of the Highlands with that in which they are now placed, in respect to communication of intelligence, to relate what happened this very year. When, after the return of the Clyde vessels for a vain search for herrings in the northern lochs, some considerable shoals having appeared, intelligence was despatched to Greenock, but, owing to the indirect course of the post, and the difficulties of some parts of the circuitous journey, several weeks elapsed before any advantage could be taken of the information.*

The lines that have been suggested, or nearly such lines, are, in the opinion of the Committee, the radical lines of road, as they may be termed, from which, in process of time, various ramifications will be formed, when the benefits of these begin to be perceptibly diffused.

From consideration of the connection of the fifth question with what precedes, the Committee in so far depart from Mr. Telford's arrangement as to put next in order the answer to it. They are fully persuaded of the reality of those views, both of public and individual benefit, which the statement of the question includes; and they think it highly reasonable that the land-owners should, according to their respective abilities, unite with Government in executing these plans, by contributing a certain proportional part of the expense, varying with the different circumstances of their several situations. But the Committee humbly report their opinion, that it would be advisable for the Lords of the Treasury, after weighing such suggestions as have been made, and consulting their surveyor, to select the lines of roads which more immediately and in a national view invite the public aid; and then, after the selection is made known, it will be the duty as well as the interests of land-owners to come forward with their proposals, stating, with regard to each separately, those local considerations which seem to fix the proportion of public aid that may fairly be solicited.

In answer to Query Second, the Committee have no doubt that the Caledonian Canal, formed on the scale suggested (sufficient for the passage of large trading ships and frigates), will be attended with the greatest national advantage. In respect to these objects, indeed, the benefit must be so incalculably great, that this truly useful undertaking assuredly merits the attention and exertions of Government. The Committee have equally little doubt in concurring with the opinion inferred in the third question, that by opening a free communication from the eastern to the western sea, it would be highly beneficial to the fisheries, particularly by transferring the skill in the cod and ling fishery possessed by the people on the eastern coast, by whom it is certainly better understood than by the natives

* The ordinary course of post was (in 1802) one week from Loxford to Tongue, and another from Tongue to Tain, being on the line from Inverness to Edinburgh.

of the western, from the former to the latter of these shores, where the field for its action is inexhaustible.

With regard to Query Fourth, the Committee are well convinced that the undertaking these public works must produce the united good consequences of checking the spirit of emigration, by affording useful employment to a great number of people, of improving the habits of the country, by teaching lessons of systematic industry, and of affording at once the excitement to undertake, and the intelligence, as well as (to a certain moderate extent) the means required for instituting those fishing and manufacturing establishments on which the future prosperity of the Highlands must be founded.

On the Sixth Question the Committee have to observe, that they are fully aware of the commercial as well as other national advantages derivable from the Caledonian Canal; but with regard to the question, to what extent commercial men would be ready to contribute individually towards carrying the same into effect, the Highland Society can have no means of forming an opinion, other than by reference to that general spirit of liberal enterprise which distinguishes the commercial body.

Adverting to a supplementary suggestion from Mr. Telford, the Committee apprehend that it would be highly expedient to introduce a clause into any Act of Parliament on the subject, authorizing and empowering proprietors of entailed estates either to sell lands for defraying the expense of contributing along with Government, to the making of roads and bridges in the Highlands, or, in their option, to make the same a debt, affecting the subsequent heirs of entail.

It has been stated to the Committee, that tutors and curators of minor proprietors, and trustees holding possession of estates concerned in these improvements, might feel some hesitation in venturing on the necessary outlays, as entertaining a doubt of such acts of administration falling within their powers. The Committee are humbly of opinion, that it would be proper to add to the clause already suggested, an enactment, that tutors and curators of a minor heir of entail, or trustees already in possession of an estate already entailed, or which is directed to be entailed, should have the same power of selling lands, or charging the estate, that is by the Act conferred upon heirs of entail; as also, that tutors and curators of minors possessed of unentailed estates, and trustees holding possession of such, should be entitled by their acts in the premises to bind the minor or trustee, and all successors to the estate.

A true copy from the Record.

(signed) *Lewis Gordon*, Dep. Sec.

Highland Society Hall,
Edinburgh, 10 Dec. 1802.

Highland Society Hall, 23 Dec. 1802.

MINUTE of the COMMITTEE of the DIRECTORS of the HIGHLAND SOCIETY of *Scotland*, which formerly drew up Answers, in the shape of a Report, to the Queries of Mr. *Telford*, Engineer, respecting the opening of Communications by Roads and Bridges in the Highlands, and by a Canal from *Inverness* to *Fort William*, upon considering a Letter from Mr. *Telford*, of date 14th December 1802, to *Henry Mackenzie*, Esq., one of the Society's Directors, owning receipt of said Report, which he states to be able, full and satisfactory; and that the 'only instance in which it is 'rather less explicit than he could wish, is with respect to the Road in the Middle 'Division, which should connect the *Inverness* and *Fort William* Road with *Skye*, '&c. &c.;' as to which Mr. *Telford* wishes the Company could say something more specific, and recommends their taking any information which can be furnished by Mr. *Donaldson*, Surveyor of Military Roads, upon that point.—The Right hon. Lord *Macdonald*, one of the Vice-Presidents in office, in the Chair.

THE Committee, in their former Report, have pointed out the great objects to which roads through the district in question should, in their opinion, apply; but there being a difference of opinion as to the precise lines of road by which those objects would best be attained, the Committee do not feel themselves at liberty to specify those precise lines. They would take the liberty of suggesting the expediency of Government employing some able surveyor or engineer of respectable character and abilities to report upon the subject; and if, relative to the present point of inquiry, they are to say any thing more particular, they may mention, that the objects of this line of intercourse seem chiefly twofold; viz. to afford a communication to the head of Loch Hourn, a very valuable fishing-loch; and also to Bernera, the nearest point to Syke; both which they apprehend may be attained by two ramifications of a road from the military road leading from Fort William to Inverness.

The Committee, adverting to Mr. Telford's suggestion of an examination of Mr. Donaldson, called him before them, but found that he had never travelled any part of the country from Fort Augustus, westward, to Bernera or the lochs, and that his information was solely, as to that part of the country, derived from others.

A true copy from the Record. (signed) *Lewis Gordon*, Dep. Sec.

APPENDIX (L. 2.)

REPORT from the COMMITTEE on Mr. *Telford's* SURVEY of the HIGHLANDS.
3 June 1803.

ROADS AND BRIDGES.

THE Committee having considered in their former Report the nature and extent of the emigrations from the Western and Northern Highlands of Scotland, and being strongly impressed with the necessity of affording immediate employment to the inhabitants of those Highlands, proceeded, in the next place, to the consideration of that part of

Mr. Telford's Survey which relates to forming an inland navigation between Inverness and Fort William, with the view of improving the fisheries and advancing the general interests of the kingdom, in war as well as in peace; but as your Committee, in order to obtain a more accurate knowledge of this subject, have thought it material to order several persons before them from Scotland, and as some time must elapse before those persons can arrive, your Committee proceeded, without further delay, to consider with attention the part of the Survey relating to roads and bridges, which they are of opinion are of the highest importance, for the same salutary purposes which the inland navigation is designed to promote; especially such of them as will open communications with the fishing-lochs and stations on the different coasts, through a district of country at present nearly inaccessible, and which forms a barrier against all probable improvement.

Your Committee are sensible that bridges cannot be built, or lines of road formed, through this mountainous and difficult country, without the aid of public liberality and encouragement. The first and original expense of such works, it is in vain to expect that the means of the proprietors of land can altogether defray; but it seems just that the land-owners should assist the public to the extent of their ability; and for that purpose it may be expedient to afford every facility for enabling them to raise such sums of money as may be necessary, as they will share the general benefit which must result from diffusing habits of industry among the people, and opening a free and ready access to the more cultivated part of the country.

It therefore appears to your Committee to be advisable, that provision should be made for the present year, by Parliament, for defraying one-half of the estimated expense of the roads and bridges which may appear most immediately necessary:

And that the remainder of the expense of making such roads and bridges should be defrayed by the proprietors of land, or other persons who may be benefited thereby; and that provision should be made for keeping such roads and bridges in proper repair:

And that, in order to provide for the proper expenditure of the public money, and in order that the said roads and bridges may be carried on with prudence and economy, it will be proper that Commissioners should be appointed to superintend and direct the execution of the same:

And that no aid of any public money should be given for such purposes, unless a survey and estimate of the expense, verified upon oath, shall have been laid before the Commissioners, and approved by them:

And that it may be expedient, by a legislative provision, to afford to the owners of entailed property a facility of raising, either by charge upon their estates, or by the sale or feu of part of them, such sums of money as may be necessary to enable them to furnish their proportion of the expense to be incurred by the making or repairing roads or bridges.

APPENDIX (L. 3.)

REPORT of the COMMISSIONERS appointed for the purposes of an Act, passed in the forty-third Year of the Reign of his Majesty King GEORGE the Third, 'for making Roads and building Bridges in the Highlands of 'Scotland;' being a condensed Statement of their Transactions during eighteen Years, 1803–1821.

Origin of the Highland Roads and Bridges.

IN the year 1802, the state of the Highlands of Scotland engaged the attention of his late Majesty's Government, and in the ensuing Session of Parliament, 'A Survey and Report of the Coasts and Central Highlands of Scotland, made 'by command of the Lords Commissioners of his Majesty's Treasury,' was referred to a Select Committee of the House of Commons, who made four several Reports to the House.

The improvement of internal communication by means of roads and bridges, essential in itself, and for the introduction of all subsequent improvements, could not but occupy the early attention of the Committee. They were naturally led to this subject, indeed, by the existence of the military roads, which, although made for a particular purpose, and with little or no regard to such ascents and descents as do not impede the passage of an army, had become so useful in a country destitute of better roads, as to demonstrate the greater benefit which could not but result from a judicious extension of what had been done; and the report which was under the consideration of the Committee developed a consistent plan of internal communication.

The military roads were begun about the year 1732, and had been prosecuted so far as to secure a practicable passage from Stirling to Inverness, and from Inverness to Fort William, in the year 1745; after which time, by a steady progress, and chiefly by military labour, they were increased to eight hundred miles in extent, of which six hundred miles were still maintained in repair for civil purposes at the expense of the public, after the military purposes of these roads had ceased.

The Select Committee of 1803 were aware that new roads could not be formed in a mountainous and difficult country, nor could large bridges be built, unless liberal aid were afforded by the legislature for the encouragement of the Highland proprietors in making a great effort for the improvement of their native country; and swayed by this conviction, the Committee recommended to Parliament what may be deemed a new experiment, in granting conditional aid for the immediate benefit and improvement of a particular district, and therein for that of the entire body politic. They advised, therefore, 'That provision should be made by Parliament for defraying one-half of the 'estimated expense of the roads and bridges which might appear most imme- 'diately necessary;—that the remainder of the expense should be defrayed

'by the proprietors of land or other persons who might be benefited thereby; '—that provision should be made for keeping such roads and bridges in 'proper repair;—and that in order to provide for the proper expenditure of 'the public money, and in order that the said roads and bridges might be 'carried on with prudence and economy, that Commissioners should be 'appointed to superintend and direct the execution of the same.'

Such was the origin of the Act of Parliament passed in July 1803, by which we were constituted Commissioners to carry into effect these beneficent intentions, and we have from time to time reported to both Houses of Parliament the great progress made, and which still continued to be made, in forming the intended roads, which with several large bridges have at length accomplished a ready access to the North Sea at Thurso in Caithness, and at Tongue in Sutherland, and to various parts of the western coast in the counties of Ross, Inverness and Argyle; all the roads being so distributed throughout the interior of the country as to have diffused habits of steady industry in making them; and so combined, as to afford to the inhabitants mutual intercourse on the largest scale, as well as a commodious passage for their cattle, and for the conveyance of all other articles of Highland production, and of Highland traffic.

At the commencement of our transactions it was uncertain whether the expectations of Parliament might not have over-rated the desire of improvement felt in the Highlands; but in the year 1804, the inhabitants of the leading county of Inverness obtained a power of assessing themselves for the repayment of such proprietors as should advance money, or interpose their heritable security, towards making roads or building bridges. In the year 1805 the counties of Ross and Sutherland followed this judicious example, and in 1806 the county of Caithness, by obtaining a similar Act, laid open before us an uninterrupted scope of improvement, over a space not over-estimated at a hundred and thirty miles in length, averaging at fifty miles in breadth.

Applications for surveys and estimates became numerous accordingly, and did not cease until seven years after the date of the Highland Road and Bridge Act;—before the expiration of which time a whole year's notice had been published, that we should not hold ourselves at liberty, after the 4th day of July 1810, to entertain any proposals, excepting for such roads and bridges as should be undertaken in consequence of one of the four County Assessment Acts.

This limited permission continued until April in the year 1816, when, in order to preclude an indefinite expenditure, of the amount of which not even a conjecture could be formed, we finally determined that no further contributions in money, nor in heritable security, should be accepted; thus extinguishing all those outstanding applications and proposals to which otherwise we should have remained eventually liable.

Amount of Grants since 1803

We were then enabled, on a review of our transactions and engagements, to form an estimate that £.240,000 would probably be the total amount of money granted by Parliament for this service; and about £.12,000 of interest money having accrued therefrom in the course of our expenditure, the large sum of £.252,000 of public money has been made applicable to that branch of Highland improvement, which consists in new roads and bridges.

£.252,390.

Amount of Contributions, £.201,799.

This munificent donation has been met on the part of the Highland proprietors with contributions to the amount of £.200,000, and although £.11,000 (part of that sum) has been returned to them in cases where the estimate exceeded the expenditure incurred, an additional sum has been paid in the opposite case, of which many instances, such as that of the Fleet Mound, occur in this Report, so that the expenditure on roads and bridges, of which we have had full cognizance, has amounted to upwards of £.450,000. This sum has been expended on eight hundred and seventy-five miles of road, and several large bridges, independent of those included in road contracts.

The average price paid for the roads has been under £.400 per mile; and the manner in which the Northern and Western Highlands are intersected by them, as well as the situation of the large bridges, will be fully understood by reference to the map annexed to this Report, and which embraces other objects,—harbour improvements, and certain Lowland roads, also consigned to our care by Parliament; but cannot exhibit the many subordinate roads which have been made by the proprietors for the purpose of communication with the Parliamentary roads, and which much exceed in quality any of the country roads heretofore existing in the Highlands.

An alphabetical List and Description of the several roads, bridges and harbours, made or improved under our care, and showing measurements, dates and other particulars, is subjoined for the more complete illustration of the map.

Expenses of Management.

It is observable that the sum contributed by the inhabitants of the Highlands appears to be less by £.50,000 than the Parliamentary grants; that sum having been expended on surveys and estimates, law agency, and (by far the greatest part of it) in enforcing the specifications of the several contracts. We have heretofore had occasion to allege and explain the unavoidable necessity of maintaining Inspectors, under whose personal observation all works afterwards hidden from observation have been performed,—such as the foundation of bridges and other masonry, the dimensions of covered drains,—in fact, the substratum of the entire road wherever it is carried along a sloping surface, and therefore supported or protected by frequent retaining-walls, breast-walls, arches and embankments; so that the durability of a Highland road especially relies on establishing and enforcing unremitted inspection of the operations of the contractor, as the general rule of the service. From this cause chiefly, the sum which has passed through the hands of Mr. Telford, our civil engineer, has amounted to no less than £.30,000, which

Inspectors.

we are convinced has been expended with the most commendable frugality, as well as that in all his plans and estimates of bridges and other masonry he has manifested the most scrupulous economy, as never having been induced, by too much anxiety for his own character, to recommend needless solidity at the expense of his employers. We were obviously induced to secure his services in superintending the improvements pointed out by himself in the Preliminary Report of 1802, already mentioned.

Certainly we were not previously aware of the extent of this sort of expenditure; nor was it perhaps in the contemplation of the Legislature, when a full moiety of the estimated expense of making roads and building bridges was promised on the part of the public; nor can we be supposed to state, as an acceptable alleviation of such inequality, that the competition of contractors has produced low prices, by which many of them have sustained loss, instead of reaping any reward of their labours, and this unquestionably to an amount far beyond the sum which, on the part of the public, we have paid for inspection and general management. As far as was consistent with our duty as guardians of the interest of the public and of the contributors, we have discountenanced all imprudent offers of contract; but we have not always been able to resist that kind and degree of urgency in the parties, which inferred a serious inculpation of our own conduct, if we had positively rejected low-priced offers supported by good security.

Law Agency.

The mass of correspondence and of money transactions imposed on Mr. Hope, our law agent at Edinburgh, may be partly inferred from the conditions of our contracts, which, allowing an advance of money at first, and retaining a similar sum at the close of the work until it shall have been finally completed, have required a calculation upon every certificate of work performed in the course of every contract; another duty which demonstrates how indispensable is the office of the Inspector, and his close attention to the progress of the work. On Mr. Hope also has devolved the delicate but indispensable task of investigating the sufficiency of the sureties proposed in every offer of contract; and we have the satisfaction of stating, that through his professional attention in preparing these contracts, and his judicious forbearance towards the contractors and their sureties on all fit occasions, we have absolutely avoided a single instance of litigation in all our multiplied transactions; the contracts to which we have been parties not having been less than one hundred and twenty in number. The sum which has been paid to Mr. Hope during seventeen years has amounted to £.10,000, about one-third of which has been in the nature of repayment for money expended in stamps, advertisements, postages, and similar contingencies; so that Mr. Hope's charges have been as moderate as his conduct has been exemplary in punctuality and incessant diligence.

Establishment in London.

The conduct of our own business in London has not been very expensive, our establishment consisting of a Secretary and Accountant, whose salaries have been paid, as well as all contingent charges, for less than £.350 per annum;

including herein a payment of £.300 for a copy and reduction of General Roy's Military Survey; which was peculiarly useful to us after the County Assessment Acts had passed, as a basis on which to delineate the boundaries of the several counties; and we trust that the publication of it was acceptable to the public, who were not previously in possession of a scientific map of Scotland:—And in mentioning Mr. Rickman, our Secretary, we cannot too highly appreciate his services, which have been afforded to the Board during the last six years with no small personal inconvenience to himself, from his other official occupations during the sitting of Parliament. Considering the great value of the business of the Board being in the hands of a person fully informed of all its proceedings from the commencement, and above all, in the hands of one so peculiarly fitted for the duties of that situation, from the variety of his knowledge, and his unwearied diligence in the discharge of those duties, we are persuaded the greatest public benefits have been derived from his labours, both in carrying the views of the Board into execution, and in preparing the materials for our successive Reports to Parliament.

Secretary.

Further Contributions offered.

Having thus explained some of the particulars of our expenditure, which has amounted to £.450,000 on roads and bridges, we must not omit a striking proof of the satisfaction which it has diffused among the Highland proprietors, insomuch that more than £.80,000, in addition to the £.200,000 actually contributed by them, and included in the above sum of £.450,000, has been pressingly offered on the same conditions; the greatest part of it, for roads to the district of Assynt in Sutherland; to Loch Maree and to Ullapool in Ross-shire; and to Hunâ (John-a-Groat's house) in Caithness; other minor roads and improvements of roads have been proposed, too numerous for mention; and the connecting road between Dunvegan and Sconser, in the Isle of Skye, lies under peculiar circumstances, which are detailed in a subsequent part of this Report.

In fact, the Highland proprietors have so largely experienced the value of their new roads, that they are not only ready to go further in expenditure for additional roads, but have arrived at desiring roads of a quality superior to what we think prudent in point of expense, or for other reasons desirable in the Highlands.

Highland and Lowland Roads distinction explained.

The difference of character between a Highland and a Lowland road is very considerable, and we have reason to think that this is not generally understood. In making a Highland road, the heaviest part of the expense is incurred in guarding against the effects of a stormy climate, and of an uneven surface, which, imbibing little water, pours down upon the Highland road torrents by which it is inevitably and immediately destroyed, unless apertures are provided of sufficient dimensions to carry under the road all the water collected in the upper side drain, and in the preventive drains above the line

of road, which convey the water directly to the covered cross drains and bridges; which last are of such frequent recurrence as to amount to eleven hundred in number on the roads made under our care.

The same climate renders accuracy of formation and smoothness of surface essential to the well-being of a Highland road; every slight obstruction of the water which falls on the road or is produced by melted snow, being apt to cause a current and gully, so that a Highland road formed of angular stones never becomes useful, because all the blending (or soft material) is soon washed away, and the road continues to be in a state harsh and unpleasant to travellers in wheel carriages, and injurious to the feet of the cattle, whose accommodation and good condition when brought to market is a primary object of all Highland road-making. It is to be understood, therefore, that in proportion as a road is frequented by wheel carriages, it may be, and also must be, covered with harder materials; in other words, that the metalling of a road with angular stones is necessary in a frequented situation; and conversely, that friction and crushing by wheel carriages are necessary to render a metalled road useful and agreeable. Hence it follows, that in the vicinity of Inverness and of Dingwall, and on the road traversed by the northern mail coach, an addition of hard materials is become very desirable; but this was not desirable when the roads were first formed, even had the expense of metalling been within our competence; but as the cost amounts to £.500 or £.600 per mile, it was impracticable as well as unadvisable, and is properly left to the future care of those who are always able to provide for such an expense by means of tolls or otherwise, when roads become much frequented, from the improvement of the surrounding country. The roads made for military purposes in the more southern counties have been gradually transformed into turnpikes accordingly, and this will unquestionably be the issue of several of the Parliamentary roads, provided the Northern Highlands continue progressively to improve in the same degree as has been evidenced during the last ten years.

Many of the Parliamentary roads, and indeed greater part of them, ought always to be maintained in their present state; and for this purpose less expense, but a greater degree of watchful attention, is requisite than would be supposed by those who are only conversant in Lowland road-making; inasmuch as the Highland road-repair inspector is under the necessity of being on the roads in proportion as the weather is wet and stormy, in order to prevent or to provide for the new direction of a mountain torrent, or to remove stones which at such times are occasionally deposited on the roads.

We shall endeavour to submit a succinct statement of our money transactions, as regarding Parliamentary grants; and of the explainable deficiency of our present funds, which will require a moderate supply in order to enable us to close our accounts in Scotland.

We have received Parliamentary Grants to the amount of £. 240,000, and interest thereupon, nearly £. 12,000; in all, £. 252,000; and we have expended, on the part of the public, £. 255,000, being at present indebted to the Bank of Scotland; to which, adding the claims and future expenses to which we are liable, the estimated deficiency amounts to about £. 8,000, which we now solicit to be granted to us; and if £. 2,000 were moreover given towards rebuilding the Torgoyle bridge, to which our road-repair funds are inadequate, all the works completed under our care would be placed in a perfect condition.

£. 240,492
£. 11,898
£. 252,390
£. 255,372
£. 8,000
2,000
£. 10,000

On the whole, we venture to hope that the detailed account of our expenditure on the part of the public, which forms part of the Appendix to this Report, will be found clear and satisfactory;—and the result of all the accounts between ourselves and the contributors, which from their nature have been very laborious and complicated, appears in a balance paper or summary view, which has been drawn up by our accountant, Mr. James Smith, with a brevity and distinctness which is very gratifying to those who have witnessed the bulk and difficulty of all the various accounts (chiefly between ourselves and the several contributors) which have been called for and stated by him from time to time.

ROADS.

Loch-na-Gaul Road.—Among the several lines of Highland road surveyed by Mr. George Brown, between the years 1790 and 1800, two of those which had reference to the western sea have been accomplished. The Loch-na-Gaul road opens a communication from the inlet so named to Fort William, by means of a ferry over the river Lochie, where the road has its eastern termination on a commodious pier. It was finished in 1812; and during the years 1817, 1818, 1819 and 1820, the repair of it has cost £. 426, averaging at £. 2. 16*s.* per mile per annum.

Measurement. Miles. 37 Yards. 1,087
Expenditure - £. 8,711 - 6

Glengarry Road.—The Glengarry road connects Loch Hourn, another and deeper inlet of the west sea, with the great valley of Scotland. It was finished in 1812, and the repair of it during the last four years has amounted to £. 577, averaging at £. 4. 11*s.* per mile per annum.

Measurement. Miles. 31 Yards. 1,068
Expenditure - £. 8,338 17 2

Moydart Road.—The Moydart road reaches Loch Moydart by turning to the northward from Loch Sunart, thus giving a double access to and from the western sea. The difficulty and delay arising from the misconduct of the contractor who undertook to make this road have been detailed in our preceding Reports. It was not finished till the year 1816, and during the last four years the repair of it has cost £. 365, averaging at £. 2. 13*s.* per mile per annum; and a sum of £. 293 for extra law charges, and a piece of road at the march or boundary of the Ardgour property, must be added to the joint expenditure heretofore stated.

Measurement. Miles. 34 Yards. 860
Expenditure £. 11,703 4 2

Argyleshire Military Roads.

The eastern termination of the Moydart road is furnished with commodious ferry piers at Corran, and thereby connects the district of Morvern, and in some degree the adjacent islands, with the other districts of Argyllshire, which are on the east side of the Linnhè Loch. Between Corran Ferry and Ballachulish Ferry, the intervening space of five miles is in the county of Inverness, and is traversed by the military road which extends thus far from Fort George along the great valley of Scotland, upwards of ninety miles.

From Ballachulish on Loch Leven (the boundary of Argyleshire), the military road to Inverary is reckoned fifty-eight miles, or indeed sixty-one miles, if an intervening space of three miles of Perthshire military road be included. This occurs at Tyndrum, and divides the Argyllshire road into two sections; the one extending thirty-one miles from Ballachulish, and called the Glencoe road, from passing through a rugged valley of that name, where it is liable to be obstructed in more places than one by stones, which in the stormy season rush down in torrents, and are deposited on the road and beyond it. This sort of damage to the road and to the valley is said to have been unknown, until the black cattle, formerly depastured thereabouts, were supplanted by sheep, whose habit of ranging on higher ground disturbs and sets in motion the rocky rubbish of the summits before it is decomposed by the weather; moreover, the passage of the water down the steep side of the mountain being interrupted by horizontal sheep tracks, it thereby acquires increased power of moving stones, which from these causes are so largely accumulated as finally to overflow and force their way down to the lowest ground.

From Tyndrum to Inverary, called the Dalmally road, is reckoned twenty-seven miles; from Inverary the road is continued around the head of Loch Fine, thence through Glencroe (another rugged valley from which this road is named) to the head of Loch Long, about twenty-two miles.

Glencoe Road - - -	31
Dalmally Road - - -	27
Glencroe Road - - -	22
Total -	80

Thus the Argyleshire military roads are reckoned at eighty miles, and have been very expensive hitherto, averaging at £.14. 6*s.* per mile per annum; but this includes the expense of rebuilding the Inveruran bridge, and of substituting covered cross drains for the shod-fords, or paved open drains, which heretofore at short intervals crossed the surface of all the military roads in a slanting direction, much to the personal annoyance of the traveller, and very destructively to the springs of modern carriages.

It will be understood, from the foregoing description of these military roads, that the maintenance of them in good condition must always be considerably expensive, probably to the full amount of £.10 per mile.

Measurement. Miles.	Yards.	Expenditure: £.	s.	d.
-	560	£. 286	13	-
1	1,480	782	11	6
1	528	228	-	-
3	808	£. 1,297	4	6

CRINAN QUAY ROAD. BALLENOCH ROAD. KEILLS ROAD. } These three short pieces of road, scarcely discernible on the map, were made to remedy defects in the county road, which affords access to the islands of Jura and Islay, Colonsay and Oronsay. The Keills ferry pier has lately been repaired and improved at the expense of the harbour fund, and

the roads at that place and at Crinan have been suitably renovated at an expense of £.140, incurred in 1819 and 1820.

Jura Road.—Answering to the Keills ferry station is that of Lagg, where the Jura road commences; and, by skirting round southward of the mountainous part of the island, reaches Feoline, a ferry station, connecting it with Islay. The Jura road was finished in 1812, and during three years was expended on it and the ferry piers the sum of £.152, averaging at £.2. 2s. per mile per annum. Mr. Campbell, of Jura, has placed milestones on the Jura road; and a short road from Lagg to East Tarbet, and thence across the island (almost divided by the sea at that place) was made, on his application in 1814, at a joint expense of £.800.

Measurement.
Miles. Yards.
16 157

18 157

Expenditure - £.4,330 6 1
+ 800 - -
£. 5,130 6 1

Islay Road.—The southern part of the road, which crosses the populous island of Islay, required and received in 1807 a thorough repair, which cost about £.100 per mile. Since that time no application was made for further repair till last year, when it cost £.78, or £.5. 4s. per mile; and we understand that in future it is likely to fall regularly under our care.

Measurement.
Miles. Yards.
14 1,259
Expenditure - £.1,512 11 10

Arran Roads.—The two branches of the Arran road, one of them extending seven miles along the east shore of that island, and the other crossing to its south-western corner, cannot but be highly useful to the inhabitants; and it is so much out of the usual round of inspection, that for some years they were permitted to repair it in their own manner, a moderate aid being allowed for that purpose; but in 1819 the road was found to be so much fallen to decay, that £.207 was then expended. In all, it has cost the sum of £.364 in the four last years, the expense averaging at £.5. 9s. per mile per annum.

Measurement.
Miles. Yards.
6 1,576
9 1,431
16 1,247
Expenditure - £.3,888 3 2

Glendaruel Road.
Riddan Road. } Arran forms part of the county of Bute, and from position is much connected with the isle of that name; from the north end of which last a communication is opened with Loch Fine and Inverary, by means of the Riddan and Glendaruel roads. The expense of repair in the last four years has been £.268, averaging at £.3. 4s. per mile per annum.

Measurement.
Miles. Yards.
18 1,705
1 1,440
Expenditure - £.3,838 11
395 -

At the junction of these two roads is placed the bridge of Ballochindrain, in such manner as also to form part of the frequented cross-road from the ferry of Dunoon to the ferry of Otter.

Strachur Road.—The Strachur road was finished in 1810, and soon becoming the most frequented line of intercourse between Inverary and Glasgow, the expense of repairing it has been considerable, and the materials are not such as tend to the permanent improvement of a road. The introduction of steam-boat conveyance will no doubt diminish the traffic on this road, which in the last four years has cost about £.3. 8s. per mile per annum; and the bridge over the water of Dreep, having been destroyed by a flood in 1818, was rebuilt of more ample dimensions, at an expense of £.225.

Measurement.
Miles. Yards.
10 1,234
Expenditure - £.2,333 10

Measurement.
Miles. Yards.
6 726
Estimate - £. 1,295 2 -
Expenditure - 1,300
Excess - 4 18 -

ARDNOE ROAD.—The small extent of the Ardnoe road, between Loch Fine and Loch Goil, and its unconnected situation, justified considerable indulgence to the contributors, who were also contractors for making it; the more so as they had been unfortunate in several attempts to build a bridge, and had incurred expenses far beyond the contract price. The road was not completed till April 1820, the expenditure on the part of the public appearing to have been £.650, while that incurred by the contributors is represented to have amounted to £.2,200; and they have applied for further aid, which in this case, as in all similar cases, we are unable to grant. Through the excessive delay which took place in the completion of the contract, this road was not placed under the Repair Act till last year, at £.6 per mile.

Measurement.
Miles. Yards.
8 888
Expenditure - £. 2,050 -

KILMELFORD ROAD.—The Kilmelford road is a considerable improvement of part of the former county road westward of Inverary. It was finished in 1814, and in the four last years the repair of it has cost £.118, averaging at £.3. 9s. per mile per annum.

Before proceeding to the Laggan road in Lochaber and Badenoch, and to the other roads in and near Strath-Spey, it will be convenient to describe the military roads with which they are intermixed and connected.

Inverness-shire Military Roads.

Miles.
52
33
30
45
176

The military roads maintained in repair in the extensive county of Inverness are the Badenoch road, from Inverness through Badenoch to Dalwhinnie, and further to the borders of Perthshire, reckoned at fifty-two miles*; the Boleskine road, from Inverness to Fort Augustus, thirty-three miles; where a road, thirty miles in extent, turning to the left over the Corriarick mountain, reaches Dalwhinnie before mentioned, and, joining the Badenoch road, enters Perthshire by a road originally military, at present under repair as a turnpike-road. The road from Fort Augustus to Fort William, and further to Ballachulish ferry, is reckoned at forty-five miles. From Inverness another military road passes along the shore to the entrance of the Beauley Firth at Fort George, and with its offset roads to the eastward is reckoned at sixteen miles, and is the most expensive road under our care. These military roads (which are reckoned at one hundred and seventy-six miles) have been greatly improved during the last five years, at an average expense of £.9, or (including casualties) of £.9. 10s. per mile per annum; but in so doing, an unequal portion of the road-repair fund has been applied to them, and must be reduced.

Measurement.
Miles. Yards.
42 568

LAGGAN ROAD.—By means of the Laggan road, which connects the Fort William military road with that in Badenoch, a communication has been in effect opened from the Linnhè Loch and the western coast, to more than one

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* *N. B.*—Strictly speaking, part of the Badenoch road (13 miles) between Freeburn and Aviemore is in Morayshire; but this is compensated by the same extent of road (north and south of Grantown), which, though really in Inverness-shire, is usually ascribed to Morayshire.

point of the Moray coast. Our last Report concerning this extensive and important road explained the delay which had arisen from insufficient estimates, and the ruin of contractors and their sureties. For remedy hereof, measures of a decisive kind were adopted, and in August 1818 the western portion of the road underwent a final inspection, which was highly satisfactory. The large bridge over the Spean is so situated that, by an easy alteration in the military road, it might be made to supersede the necessity of rebuilding High Bridge, should any destructive accident occur to that lofty structure. The course of the river Spey at Laggan has been turned so as to secure the bridge from the effects of a cross current, and nothing is wanting on the whole road except an inn or inns at commodious distances. In this defect we cannot interfere, further than to point it out to the attention of those proprietors who have power to build or to adapt houses for this purpose.

A strict comparison of the successive estimates with the ultimate expenditure on the Laggan road, and in restraining the course of the river Spey, would be very difficult, from the distressing circumstances detailed in our last Report. The estimate dated in 1809 was considered as very exorbitant, amounting to £.16,750; and of this, £.9,043 was assigned to the eastern division, the expense of which did not materially exceed the estimate, but a heavy loss fell on the contractors. The western division seemed to elude all calculation, and the several sums paid for it have amounted to £.12,651. Besides this, the new river-course at Laggan bridge cost £.1,593. Thus the ultimate expense of the Laggan road became £.23,293, an appalling sum; but the expectations from this road are such, that we have not heard of any regret expressed by the contributors, whose remonstrances through successive years overcame our repugnance to engage in what we foresaw would be a most expensive work.

Estimate -	£.9,043	-	-
Expenditure -	9,048	15	-
Excess - -	5	15	-

Paid to			
Messrs. Clarkes	£.2,536	10	
Mr. Davidson -	7,247	19	1
Mr. Wilson - -	2,866	11	4
	£.12,651	-	5

Paid for Cut at Laggan Bridge,	£.1,593	8	5

Recapitulation:

East Division	£.9,048	15	-
West Division -	12,651	-	5
River Cut - -	1,593	8	5
	£.23,293	3	10

The expense of repairing the Laggan road, and maintaining the new river-course (mentioned above), was £.170 in 1819, and £.195 in 1820, averaging at £.4. 6*s*. per mile per annum.

There are considerable bridges over the Calder and the Roy.

Strath-Spey Road and Bridges.—This road includes three bridges, over the Nethy, and two smaller streams in Strath-Spey, thereby completing an improvement in the district road, undertaken, but not entirely finished, by the late Sir James Grant. The expense of repair has been very small.

Measurement.

Miles.	Yards.
1	1,019

Expenditure - £.1,567 11

Spey-side Road.—The Spey-side road was applied for by the county of Inverness later than some others, which were not so soon completed. It extends from Grantown Bridge, northward to the river Avon; and the contract was so far enlarged as to include a very substantial repair and improvement of the said bridge, by which the military road crosses the Spey, and of the road between that bridge and the village of Grantown; and the same opportunity was taken to improve the bridge over the Avon near Ballindalloch. The

Measurement.

Miles.	Yards.
12	591

Spey-side road is one of the best specimens of Highland road-making, and (what we have found to be very unusual) was finished in the year 1817, a year earlier than the time limited by the contract.

Estimate - £. 6,742 12 9
Expenditure:
£. 5,990 - -
+ 473 - -
+ 271 10 -
6,734 10 -
Saving - - 8 2 9

Upon settlement of the accounts, it appeared that the sum disbursed by the Commissioners on the part of the public (including the improvement at Grantown Bridge, and of Avon Bridge) had not exceeded the estimated expense. The repair of this road, which is equally divided between the county of Inverness and those of Moray and Banff, is contracted for at £. 3. 3*s.* per mile per annum. The Adrie Bridge is on the Morayshire part of the road.

Morayshire Military Roads.

12

6

9

27

From Grantown to Aviemore (the head of Strath-Spey), a military road, extending southward twelve miles, forms part of the communication from the Laggan road to the Spey-side road; and a road branching from it, along the north side of the river Dulnain, called the Duthel road, has lately been renovated, at an expense of £. 600 (or about £. 100 per mile), for the purpose of opening a more direct intercourse with Inverness, and is likely to be productive of stage-coach conveyance from Banff in that direction. The military road from Grantown extends, northward, nine miles to Dava or Tominarroch, where it is met by a branch of the Findhorn road, and thus conduces with it in forming access to the coast at Nairn and at Forres.

Measurement.	
Miles.	Yards.
12	565
1	802
-	260
13	1,627

Estimate - £. 3,770 12 5
Expenditure - 3,802 12 5
Excess - - 32 - -

Findhorn Road.—The Findhorn road is thus connected with the military roads; and by its branching form, and its bridge over the river from which it takes its name, facilitates, indeed has created, a very useful intercourse between the coast-towns and the interior of a valuable district. The contributors to this road were Sir James Montgomery Cuninghame, and Mr. Grant of Rothiemurchus. It is in the county of Nairn, and the expense of maintaining it in due state of repair has been £. 175 in the last four years, averaging at £. 3. 3*s.* per mile per annum.

Measurement.	
Miles.	Yards.
19	1,128
6	1,156

Expenditure - £. 4,128 7 2
725 18 6

Inverfarigag Road. } Ballichernoch Road. } These roads, at their western termination, communicate by a landing-pier with Loch Ness; and from thence, through Stratherich and Strathnairn, joining the Moy road, afford an access, somewhat circuitous, to the town of Inverness. The repair of these roads has amounted to £. 269 in the last four years, averaging at £. 2. 8*s.* per mile per annum.

Measurement.	
Miles.	Yards.
14	694

Expenditure - £. 3,374 11 3

Moy Road.—All the roads northward and westward of the town of Inverness, in fact, all those hereafter to be described, centre at that place, from whence the southern outlet is the Moy road, which therefore attracted early attention. It constitutes an essential improvement or renovation of the former military road; and (as may be supposed) requires assiduous reparation, the expense of which, during the last four years, has amounted to £. 302, averaging at £. 5. 16*s.* per mile per annum.

BEAULEY ROAD.—The Beauley Road proceeds from Inverness, westward, to the Lovat Bridge, and by an exertion of liberality on the part of the heritors of Inverness-shire, is extended two miles farther, to their utmost limit, thereby accommodating the inhabitants of Ross-shire, and of the more remote counties. The expense of repairing this road during the last four years has amounted to £.332, averaging at £.6. 3s. per mile per annum.

Measurement.
Miles. 13 Yards. 770
Expenditure - £. 7,797 5 10

STRATH-GLAS ROAD.—The Strath-Glas Road is connected with the Beauley road, from which it branches off near to the Lovat Bridge, and penetrates into a part of Inverness-shire, heretofore secluded and inaccessible. After passing by the Falls of Kilmorach, it is carried along the north side of a rugged valley (called the Dream), at no small expense, a great quantity of masonry being indispensable for the various purposes of retaining-walls, breast-walls and parapets; and indeed this whole line forms an excellent specimen of difficulty overcome by a judicious application of skill and experience in the art of road-making. The bridges over the Varrar and the Cannoch are considerable structures, and there is a large arch over the Diak, near the south-west termination of the road. The moderate expense of repairing this road proves the solidity of the workmanship; in the last four years it has cost £.277, averaging therefore at £.3 per mile per annum.

Measurement.
Miles. 23 Yards. 660
Expenditure £. 13,051

INVERMORRISTON ROAD. FORT AUGUSTUS ROAD. } The Invermorriston and Fort Augustus roads, taken together, are co-extensive with the length of Loch Ness, and the greatest part of them being unavoidably carried along a precipitous slope, required almost as much masonry as the last-described road in Strath Glas; but the inadequacy of the estimate of these Loch Ness side-roads, both as to specification and prices, and the loss sustained by the contractor, and his cautioner, Sir John Campbell, justified large augmentation on future occasions. A Highland road is less expensive in proportion as it is accommodated to the sinuosities of the mountain-sides, instead of attaining a more direct line by alternately cutting into the rock, and forming embankments over gullies and dingles; and from frugality in these operations, the Loch Ness side-road exhibits sudden turns, where the protection of the traveller is less perfect than might be wished. Portions of its masonry have been sometimes carried down the precipice, so that vigilant attention is requisite to maintain this road in a passable condition.

Measurement.
Miles. 21 Yards. 1,225
6 75
Expenditure - £. 4,891 19 4
856 9 -

The necessity of providing for the repair of the Parliamentary roads was first demonstrated by the state into which the Loch Ness side-roads had fallen, from the time when finished in 1812 to 1814, subsequently to which it was thoroughly repaired. In the last four years the expense has amounted to £.627 on the Invermorriston and Fort Augustus roads, averaging at £.5. 14s. per mile per annum.

A small bridge at Borlam, having failed, was rebuilt under a separate contract.

Measurement.
Miles. Yards.
12 540

Expenditure - £. 5,178 14 -

LOCHIE-SIDE ROAD.—Our expectations of establishing a road from Inverness to Fort William, along the farther side of the great valley of Scotland, have not been realized, chiefly because no contribution was offered for continuing the Lochie-side road to the north end of Loch Lochie. This, however, was no reason for abstaining from doing what was practicable; and by making a road parallel with the river Lochie, and farther to the foot of Loch-Arkegg, a large tract of country is rendered accessible, the lake of that name extending ten miles westward.

The northern part of the Lochie-side road suffered much from the carriage of timber in the year 1819; so that the expense of repairing it in the last four years has amounted to £.270, averaging at £.5. 10s. per mile per annum.

Measurement.
Miles. Yards.
14 469

Expenditure - £. 4,630 4 8

GLENMORRISTON ROAD.—After struggling with many difficulties, we have been successful in establishing an extensive communication quite to the western extremity of the county of Inverness, and the Glenmorriston road may be deemed to have been the first step towards attaining that object. It extends from the Loch Ness side-road up the valley of the Morriston, which river is crossed at Torgoyle, where the bridge of three considerable arches was destroyed in January 1818, and the bridge of Drumindrochet, at the lower end of the valley (not built under our care) was much injured at the same time. These bridges have been repaired with timber, but the situation is such that nothing but iron bridges can be relied upon as likely to be permanent. The Glenmorriston road has been serviceable for the conveyance of timber, but has, for that reason, and from the above accidents, been expensive to the road-repair fund, in four years amounting to £.550, averaging at £.9. 10s. per mile per annum. The upper bridge over the Morriston at Kaun-a-crok is not inconsiderable.

Measurement.
Miles. Yards.
21 1,522

Estimate - £.		14,992	11	10
Expenditure.				
14,805 10 -				
+ 13 13 -				
Parapets 99 5 6				
		14,918	8	6
Saving - -		74	3	4

GLENSHIELL ROAD.—The Glenshiell road is a continuation of the last-mentioned road, but was not begun till long after the other was finished. Much of this delay arose from its being partly in Ross-shire, though very remote from the populous parts of that county. Individuals were at length found who foresaw enough of contingent benefit to induce them to contribute towards making the Ross-shire part of the road, and the whole road was finished, much to the credit of the contractors, at the time appointed, being less than three years. An obstruction to the repair of part of this road has lately been removed. The expense actually incurred in the last three years has been £.295, averaging at £.3. 8s. per mile per annum.

Measurement.
Miles. Yards.
10 592

Estimate - £.		6,901	6	4
Expenditure:				
6,850 8 -				
+256 - -				
		7,106	8	-
Excess -		205	1	8

RHIEBUIE ROAD.—The Glenshiell road is rendered more extensively useful by the Rhiebuie road, which branches from the middle of it southward, and crossing the river Lyne or Loyne, affords a passage, especially for cattle, down Glengarry to Fort Augustus, and thence over Corriarick to Dunkeld or Crieff. The same contractors who finished the Glenshiell road exerted little diligence on this secondary road, which, however, at length was completed, and in a satisfactory manner, in August last. The estimate and specification had

scarcely done justice in its description of this road, which was a more arduous task than the contractors had reason to expect; and this forms no insufficient excuse for the unexpected length of time consumed in finishing it.

Glenelg Road.—Between Shiell-House (where the glen of the same name terminates) and Kyle-Rhea, the mountainous ridge called Marn-ratachan extends itself from north to south, and cannot be avoided by circling round the coast on its declivity, because such a road would be overwhelmed and obliterated by the decomposed rock, which is there put in motion by every violent storm. The Glenelg road, therefore, is made to ascend the face of the mountain, not without many windings, and taking advantage of every favourable slant of surface, requiring, indeed, patient labour in the traveller, but affording him a secure passage to Glenelg, to the Kyle-Rhea ferry, and thus into the Isle of Skye. This road was not quite finished till the autumn of 1819, and at a considerable loss to the contractor and his cautioners, which must account for the unexpected delay; and this is another case in which we have to regret the loss incurred without being able to give any hope of indemnification.

Measurement.

Miles.	Yards.
11	824

Estimate -		£. 9,793 12 10
Expenditure:		
	£. 8,536 14 –	
	+508 9 6	
	9,045 3 6	
	239 8 6	
		8,805 15 –
Saving -		£. 987 17 10

Isle of Skye Roads.—The Isle of Skye is an extensive and valuable portion of Inverness-shire, and the proprietors have so amply availed themselves of the assistance of public munificence, that full one hundred miles of road have been accomplished, and almost entirely by the hands of the islanders, who have thus acquired habits of productive industry, and such skill in the use of more efficient tools, that scarcely a specimen of the cumbrous *cas-chrom* is to be found on the island. It is a rude combination of a lever for the removal of rocks,—a spade to cut the earth,—and a foot-plough to turn it withal. We have procured, and inserted in the Appendix, a description of this ancient instrument of Highland cultivation, lest it should fall into entire oblivion.

Sconser Road. }
Broadford Road. } The inn and post office of Sconser is situated on the shore of a sea-loch or inlet, twenty-three miles from the ferry of Kyle-Rhea, and to this place the Sconser road extends. A branch road turns off at Broadford (half-way between Kyle-Rhea and Sconser) and penetrates the southern district of Sleat to Armadale and Ardavaser Bay.

Measurement.

Miles.	Yards.
23	555
15	1,590

Expenditure - £. 7,980 4 –

Portree Road.—From Sconser to Portree the road is named from the latter place, which is the market town of the island. The unforeseen obstacles which seem to have been encountered on this line of road, not only delayed the completion of the contract to a protracted period, but have created additional expense to the public in prolonged inspection, and a heavy loss to Colonel Macdonald, of Lyndale, who lent his name to the contract; he has consequently applied for remuneration, which we have not the power of affording to him, however much we may regret his loss. Nor are we able to settle the account of this road, from a claim for what he conceives to have been extra work having been submitted to reference (as provided for in all our contracts), he

Measurement.

Miles.	Yards.
12	1,071

Contract Price, £. 5,000 - -

not having thought fit to be satisfied with a concession offered to him for the purpose of closing this the last of unsettled road-making contracts.

Measurement.
Miles. Yards.
19 730
Expenditure - £. 4,237 15 -

SNIZORT ROAD.—This road, which passes by the head of Loch Snizort, connects Portree with Dunvegan, on the opposite coast of the island. This road cannot boast of a strait direction, but it is formed of sound materials, and wears well.

Measurement.
Miles. Yards.
9 1,606
Expenditure - £. 3,678 12

STEIN ROAD.—The North-Stein road depends upon the last-mentioned road for its connection with the main land, and was finished in the year 1816. Macleod, whose residence (Dunvegan Castle) is adjacent to this road, remains very desirous of extending it to a junction with the Portree road at the head of Loch Sligachan, as stated in the introductory part of this Report.

Measurement.
Miles. Yards.
15 528
Estimate - £. 7,605 6 8
Expenditure - 7,605 6 8

TROTTERNISH ROAD.—In travelling from Portree on the Snizort road, its direction appears to be nearly northward for four miles, until at a hill called Culeagrummie, it turns to the westward; and here the Trotternish road commences, assuming a steady direction towards the Aird of Trotternish, the northern extremity of Skye. Lord Macdonald, the proprietor of this part of the island, was at first desirous of carrying the road quite to the Aird, and a survey and estimate was prepared accordingly. But upon further examination the estimate was found to be inadequate, and we hesitated at making the road to that extent, there being no frequented port at the Aird, and the whole object being avowedly the improvement of a district reported to be capable of bearing corn sufficient for the supply of the whole island, if rendered accessible. On inspection of the map, it was supposed that the road might answer this purpose if it terminated with a bridge at the head of the bay of Uig, and the contract was at first undertaken by Lord Macdonald to that extent. But his Lordship, in 1818, represented the difficulty of reaching this place from the remote part of the district, unless the road extended a mile and a half farther, over ground so difficult that the estimate amounted to £. 1,221: he further stated that the immediate benefit of employment would be so great to his then distressed tenantry, that he was willing to contribute a moiety himself without expecting reimbursement, by withholding his assessment money from the county fund, which has been the usual arrangement in Inverness-shire. His proposal was accepted, and the road became fifteen miles and a half in length, the contract price, £. 7,605; for which sum the road was completed in October 1819, and we understand gives great satisfaction.

Measurement.
Miles. Yards.
4 360
Expenditure - £. 2,481 17 -

ASHEIK ROAD.—The only road in Skye remaining to be adverted to, is that which connects the island with Ross-shire, and which, commencing at Lussa Bridge (on the Sconser road) extends four miles northward, passing by Asheik, and terminating at the landing pier, or small harbour, which has been since made on the south side of the ferry of Kyle Haken.

All the roads in Skye are repaired under one contract, and no material casualty has occurred except at Lussa Bridge, which became impassable in October 1819, and was rebuilt at an expense of £. 413. It was one of those

which were suffered to remain when the Sconser road was renovated under our care (1807-1812), and has justified the opinion then formed that it might be serviceable for several years.

The ordinary repair of the roads in Skye has amounted to £.1,015 during the last four years; they are such as will continue to cost about £.4 per mile; but no specific rate can yet be mentioned, two of the roads being recently finished.

BLACK ISLE ROAD. KESSOCK BRANCH ROADS. } The counties of Ross and Cromarty are so much intermixed, that for all road-making purposes, they are considered as one county. The Black Isle (so called) extends from the town of Cromarty to the river Conan;—and from Fortrose (opposite Fort George) to Conan Bridge, an excellent road was marked out under circumstances detailed in our last Report, and was finished in October 1817; with an approach to Fortrose Harbour, which cost £.82. The surplus of our moiety of the estimated expense, and the interest accumulated upon it, amounted to £.1,253, which we made over to the contributors on their undertaking to complete two branch roads to Kessock Ferry, over against Inverness. The estimate and contract price for these roads (together ten miles in extent) was £.3,520, so that the contributors expended about £.1,000 more than the public in opening this useful communication.

Measurement.

	Miles.	Yards.
	14	708
	10	-

	£.	s.	d.			
Estimate:	£.10,194	2	3			
	+ 81	12	2			
				10,275	14	5
Expenditure:	£.8,472	9	-			
	50	-	-			
	81	12	2			
				8,604	1	2
Saving -				£.1,671	13	3

Estimate - -	£.3,520	17	6
Expenditure - -	3,520	17	6

DINGWALL ROAD.—Between the northern border of Inverness-shire (noticed as the limit of the Beauley road) and the town of Dingwall, the distance is about eight miles, divided into unequal parts by the river Conan; and the old road was maintained (somewhat imperfectly) by two Ross-shire districts. In the year 1819, a representation was made, that in consideration of this being an unavoidable portion of the Great North Road, it ought to be placed under our care by the Road Repair Bill then before Parliament. We had no objection to this, provided the county at large, instead of the districts, undertook to defray a share of the expense; and the road has since been substantially repaired to the amount of £.200 per mile, so that the Conan Bridge is now approachable in a becoming manner.

LOCH-CARRON ROAD.—The extensive line from Dingwall to the western coast of Ross-shire has usually been called the Loch-Carron road, and has been made under various contracts, some of which have presented unusual difficulty in their progress or result.

CONTIN DIVISION.—The Ross-shire Road Assessment Act received the Royal Assent in June 1805, and at the ensuing Michaelmas county meeting, arrangements were made for the re-survey of several lines of road, among which the Loch-Carron road soon became prominent, and a survey, with an estimate, was directed to be prepared; but from some unaccountable delay was not authenticated till May 1807. The survey of that part of the road nearest to Dingwall had been prohibited (it was said) from an uncertainty which prevailed as

Measurement.

Miles.	Yards.
7	1,210

to the most eligible direction of it; but early in 1809 a pressing application was made by Sir George Mackenzie, recommending immediate progress; and to expedite the affair, he also transmitted a plan and estimate, which upon examination were judged by Mr. Telford to be improper and insufficient; and Mr. Mitchell was directed to prepare another plan, so as to avoid the morass near Dingwall by a road on higher ground, and to insure to the public permanent accommodation by the use of more solid materials than were proposed. From this difference of opinion arose a delay of some years in duration, and we became apprehensive that the first section of the Loch-Carron road would not be made at all. In May 1813, Sir George Mackenzie renewed his remonstrances, expressing his conviction, "That a gravelled road well made is preferable to one metalled," (that is, formed of broken stones), and that "Roads made over moss are the most agreeable and durable of any." A minute of the Michaelmas county meeting in support of the wishes of Sir George Mackenzie was afterwards transmitted, and thus urged, we at length consented that the trustees of the district should make the road in the line proposed four years before, provided they undertook to construct it in a substantial manner, above the reach of floods, and for the sum specified in Mr. Wilson's estimate. A contract undertaken after such discussions was not likely to be satisfactory in the result, but in October 1817 it was finished in the best manner we were able to enforce. Since that time the road near Dingwall has continued to be soft and muddy, and an unusual quantity of materials for building having been carried from Dingwall Harbour to Coull last year, the expense of maintaining the road in a passable condition was £.302 instead of £.56, at which it had been estimated. In fact, the Contin road requires an addition of hard materials near Dingwall to the amount of £.750, and elsewhere to be improved to the amount of £.250.

Estimate -		£.1,966	2	6
Expenditure.				
£.1,966 2 6				
78 15 3				
		1,887	7	3
Saving -		£.78	15	3

The formation of the Dingwall canal and basins superseded the eastern section of the Contin road in such manner that £.79 was saved, in diminution of the contract price.

Measurement.
Miles. Yards.
22 705

Auchnasheen Division. — The contract for making the Auchnasheen Division of the Loch-Carron road has been unfortunate, and injurious to all the parties concerned in it. The estimate was prepared by Mr. Cumming, and certified by him in May 1807, amounting to £.5,592; and in 1809, John Mackintosh undertook a contract at £.4,805, the road to be completed at the end of the year 1811.

The price of labour and of provisions had risen and was then rising, so that it was not without much unwillingness on our part that his imprudent offer was accepted, but the evil consequence of low-priced contracts was not then sufficiently ascertained, or rather was not so notorious as to enable us to reject an offer apparently advantageous to the public and to the heritors of the county of Ross.

The contractor commenced his operations at Contin, where his new bridge was destroyed by a river flood in 1811; the dimensions however were confessedly inadequate, and another bridge, with increased water-way, was built by Mr. Muirson under a separate contract. John Mackintosh proceeded very slowly till 1813, from which time he only maintained the eastern part of the road in a condition passable by carts. The recollection of what had happened in the case of the Moydart road, deterred us from pressing the contractor and his sureties to relinquishment and arbitration, and it was agreed in 1817 that the western part of the Auchnasheen Division should be placed under a new contractor. It was undertaken by Charles Innes at £.3,050, which he again considered to be an inadequate price, and he abandoned his work in October 1818, his sureties incurring some loss, but he had not been overpaid for the progress made by him.

Thirdly, Mr. Reid undertook to complete the bridges on this part of the road, and Mr. Alexander Christie the road-way, and in October 1819 the whole was finished, ten years after it had been commenced; the sum actually paid to the several contractors having been £.7,058 in place of £.5,315, to which the original contract had been augmented by successive estimates of enlarged and additional bridges. Thus the sum of £.1,743 remains due by the sureties of the original contractor, of which sum there is reason to expect, notwithstanding the unavoidable perplexity by which the affair is embarrassed, that £.1,000 will be recovered. In that case the expenditure of the public and from the county funds will be rather less than a moiety of the estimated expense of making this portion of road.

£.7,058	-	-		
5,315	-	-		
£.1,743	-	-		

Estimate:						
£.5,592	7	6				
+ 509	18	8				
				6,101	18	2
Expenditure:						
£.7,058	3	2				
Receivable from Sureties £.1,000	-	-				
				6,058	3	2
Saving			-	£.43	15	-

Luip Division.—After the foregoing detail of transactions under the Auchnasheen contract, we may venture to think it fortunate for all parties that no offer was made to undertake the Luip Division at or within the estimated expense, whereupon a new estimate became necessary in justice to the heritors of Ross-shire, and it amounted to £.7,787. Malcolm Davidson became the contractor in 1812, engaging to complete the work in 1817 for the sum of £.7,628, and at the close of the year 1818 it was taken off his hands. Three small bridges were afterwards thought necessary to be added at the estimated expense of £.50, and were built by another contractor. This division of the Loch-Carron road includes two similar and remarkable bridges over the Aultmore and the Redburn.

Measurement.

Miles.	Yards.
16	15

Estimate:						
£.7,786	11	4				
+ 50	-	-				
				7,836	11	4
Expenditure	-	-		7,623	14	-
Saving	-			£.212	17	4

Jean-Town Division.—The road extending from Coulachs at the head of Loch Carron to the prosperous fishing village of Jean-Town and farther to Strome Ferry, is one of those which have cost us no trouble or expense in urging its completion; Mr. Mackenzie, of Applecross, himself having lent his name to the contract, and bestowed attention on the conduct of his sub-contractor. The road was finally inspected in May 1817, and additional parapets, to the amount of £.120, have since been added in lieu of other work deemed unnecessary to be executed, still leaving a saving of £.75 upon the estimated expense.

Measurement.

Miles.	Yards.
10	315

Estimate	-	£.3,670	13	-
Expenditure	-	3,595	10	3
Saving	-	£.75	2	9

The expense of repairing this road and the Luip road, since both were finished, has amounted to £. 3. 10 *s.* per mile per annum.

Measurement.			
Miles.	Yards.		
14	660		
Estimate -	£. 5,126	16	
Expenditure -	5,300	16	
Excess - -	174	-	-

Kishorn Road.—Loch Carron, a navigable inlet of the Western Sea, having been rendered accessible from the towns and ports of the eastern coast of Ross-shire, Mr. Mackenzie, of Applecross, represented to the Commissioners that much benefit would be derived from extending the road northward, fourteen miles, from Jean-Town to Loch Kishorn and Loch Torridon. A survey and estimate having been accordingly made in the year 1814, a contract at the estimated expense was undertaken by Mr. Mackenzie in March 1815, and he completed it in August 1819. On this road the balance of extra work was in favour of the contractor to the amount of £. 174; the expense of repair in 1820 amounted to £. 45, or £. 3. 3 *s.* per mile.

The Commissioners did not think fit to accede to the wishes of Mr. Mackenzie, who applied for an additional piece of road, by which to attain more complete access to Loch Kishorn, with a view to the establishment of a fishery station on that part of his property.

Measurement.		
Miles.	Yards.	
13	1,560	
2	1,450	
Expenditure - -	£ 4,184	16
	720	-

Loch-Alsh Road. } Ardelve Road. } The district of Loch Alsh is bounded by Loch Carron on the north; and the Ferry of Strome is connected with that of Kyle-Haken by the Loch-Alsh road, which thus forms a communication from Ross-shire to the Isle of Skye. A branch of this road eastward was also made under the name of the Ardelve road, which is terminated by the Dornie Ferry across Loch Ling.

The expense of repairing these roads in the last four years has amounted to £. 175, averaging at £. 2. 12 *s.* per mile per annum.

Measurement.			
Miles.	Yards.		
9	1,340		
Estimate -	£. 10,259	1	5
Expenditure -	10,611	6	11
Excess	- 352	5	6

Kintail Road.—The Kintail road, in connecting the last-mentioned roads at Shiell-House with the roads directed to the eastward and southward, accomplishes an object most essential to the inhabitants of the south-western part of Ross-shire. The estimated expense of making this road was so great as to induce the contributors to apply for various estimates calculated for a road ten feet wide and twelve feet wide, as well as for the usual width of fifteen feet, which last has been upon consideration preferred by them, and was carried into execution, the whole expense exceeding £. 10,000 for ten miles of road; there are indeed two considerable bridges included in it, one over the Shiell, another over the Croe, and much masonry for various necessary purposes.

The several contracts, three in number, were completed in July 1819, and the ruggedness of the shore of Loch Duich rendered necessary certain deviations from the surveyed line, and additional masonry, which has caused an excess beyond the estimate to the amount of £. 352.

The expense of repairing this road in the years 1819 and 1820 was £. 80, or £. 4 per mile.

Loch-Alsh Ferries.—Of the Ferry-Piers connected with Loch Alsh, those at Strome-Ferry on Loch Carron, that on the Ross-shire side of Kyle-Haken,

and that at Ardelve (the western side of Loch Ling) were estimated at £.1,048, and an excess of £.24 beyond this sum was paid for extra work. The pier at Dornie (the eastern side of Loch-Ling) was estimated and contracted for at £.384, and a small saving of £.6. 10 s. occurred upon settlement with the contractor. The Kyle-Haken pier or harbour, in Skye (terminating the Asheik road there) is a considerable work; it was estimated at £.1,500, and is likely to cost that sum; indeed the contractor is dissatisfied, and intends to have recourse to arbitration, so that the account with him cannot yet be closed.

Estimate	£.1,047	18	8
Expenditure	1,072	-	8
Excess	24	2	-
Estimate	383	11	6
Expenditure	377	1	6
Saving	£.6	10	-

Fearn Road.—The town of Dingwall, situate at the head of the Cromarty Frith, is the central point of communication in Ross-shire; from it proceeds the great road to the western side of the county, which we have been describing, and from it also is continued the great road to the northern coast of Great Britain. The portion of it nearest to Dingwall is called the Fearn road, from its terminating at that place, and upon final inspection in September 1817, it was pronounced to be one of the most perfect lines in the Highlands. It is carried over a ridge of high ground in a very scientific manner, and presents a difficulty of another kind at the Allness bridge; than which place no better station can be found for viewing an example of the expedients successfully adopted in Highland road-making.

Measurement.

Miles.	Yards.
24	890

On the final inspection of this road, various articles of extra work were found to amount to £.182 beyond the estimated expense, one-half payable by the Commissioners. Midway from Novar to Fearn the water of Rivie or Balnagowan is crossed by means of a considerable arch, and near the north end of the road is the Fearn bridge. The expense of repairing this road during the last three years amounted to £.302, averaging at £.4. 3 s. per mile per annum.

Estimate:						
£.10,494	19	7				
+ 105	15	4				
				10,599	14	11
Expenditure:						
£.10,400	-	-				
+ 105	15	4				
63	2	-				
213	-	-				
				10,781	17	4
				£.182	2	5

Balnagowan Bridge.

Cross Road to Tain.—The situation of the town of Tain, which surpasses Dingwall in population, is to the eastward of the Great North road, and in such manner that no more than eight miles of the Fearn road are common to both objects, the road or roads to Tain turning off to the right at Novar Deer Park. From this place to Tain is fifteen miles, or seventeen miles to the traveller who prefers the Shore road along the north side of the Cromarty Frith, which is in use by the northern mail coach, and has on it post-office stations at Invergordon and Park-hill. We are authorized by the Road Repair Act of 1819 to repair this road, with a view (as we conceive) to facilitate the passage of the northern mail. Our attention has been called to the rival road to Tain by Kincraig; but we cannot suppose that two roads nearly parallel were intended by the legislature to be placed under our care, or that we ought to leave the Shore road to the care of the district, because it is said to stand less in need of repair than the other. Our road-repair fund is not in such a state as to admit without inconvenience the force of such an argument, even were we of opinion that, consistently with the intentions of Parliament,

Invergordon Road.

we should be justified in repairing any other than the present mail-coach road.

Measurement. Miles. Yards. 13 1,182

TAIN ROAD.—From what has been stated of the situation of Tain, it results that any road from it in a western direction must fall into the Great North Road, and this is accomplished at the distance of eleven miles from Tain, where the Fearn road terminates in the Tain road; which therefore (according to the arrangement of our contracts) itself becomes the north road for two miles to Ardgay, where a new inn (founded on a removed corner-stone of the former house) affords good accommodation. At this place, turning to the northward, Bonar bridge is in view at the distance of less than a mile.

Yards. 1,496.

Estimate - £. 8,003 19
Expenditure - 8,003 19

After a delay which has not been explained, but which only threw upon the contractor the expense of maintaining the Tain road, he put it in a proper state for final inspection in June 1817; when deficiencies and extra work balanced each other with sufficient exactness, so that the contract price was not altered by the settlement of accounts.

The expense of maintaining this road in repair during the last three years amounts to £.191, averaging at £.4. 10*s.* per mile per annum. Part of the road passes through an extensive plantation of fir trees, and is difficult to be kept in good condition.

SUTHERLAND COAST-ROADS.

Measurement. Miles. Yards. 2 638

Expenditure - £. 1,616 1 -

CREECH ROAD.—The Dornoch Frith being headed and crossed by means of Bonar bridge (of which we shall speak in due place), a road turning eastward two miles in extent connects it with the Skibo road, which was previously adapted to the former ferry near Creech. The Creech road is carried along difficult ground, and was expensive, but is as excellent in formation and durability as might be expected from the contractors for the Bonar bridge.

Measurement. Miles. Yards. 16 267

Expenditure - £. 4,557 - -

SKIBO ROAD.—The Skibo road, which originally terminated at the Little Ferry, has since been directed to the Fleet Mound, whereby the use of that ferry is superseded; so that this road, lengthened to Bonar bridge at its west end by the Creech road, and to Fleet Mound at its east end by a road of similar extent, becomes connected with the abolition of two ferries, the most striking instances perhaps of the improvement of Highland communication effected under the Road and Bridge Act.

The particular line of road now passing by Skibo was a source of much discussion before it was adopted; and the middle of it has been hitherto kept damp by the shade of a fir plantation, beyond which the soil is unfavourable. In the summer season this part of the road is smooth and pleasant; and we took the earliest advantage of the means afforded us by the Road Repair Act of 1819 to expend £.280 in rendering it more solid for winter use.

An excellent new inn has been built on this road by the Marquis of Stafford, at Clashmore, the nearest point to the Mickle Ferry, which, before the existence of Bonar bridge, was the only practicable mode of reaching Sutherland and Caithness from the south.

At Clashmore, the mail coach leaves the Skibo road (for the purposes of the Dornoch post-office) and rejoins it on the summit of the Dornoch moor. The country road made for this purpose is not unexceptionable as to its materials, but is much better in form and direction than could have been anticipated.

Near Fleet Mound the road was made under a distinct contract, embracing nearly four miles on each side of Strath-Fleet, at the expense of £.2,500.

Measurement. Yards. 995

FLEET MOUND.—This great work seems to have been first projected by the Marquis of Stafford, or rather by Earl Gower, who cultivates an experimental farm on the shore of Strath-Fleet. This strath or valley extends far up the country, and into a district so rugged and mountainous that no practicable pass could be discovered; that through Strath-Carnoc being at such elevation as to be liable to obstruction from snow during the winter months. The difficulty appeared to be insuperable, and what had been accomplished by the bridges of Dunkeld, Lovat, Conan and Bonar, was likely to fall short of the great object of establishing a communication, unbroken by ferries, to the extreme north of Scotland.

The Marquis of Stafford offered to contribute £.1,000 beyond the moiety of the estimated expense of the mound, in consideration of the contingent benefit derivable to his property from shutting out the sea (which covered about four hundred acres above the proposed site of the mound), and to expend £.200 on the sluices. With such encouragement, we did not hesitate at adopting the only practicable mode of carrying a road across Strath-Fleet. The embankment or mound is of the most solid kind, to the extent of nearly one thousand yards in length, and the road-way upon it is defended from the surge and spray of the sea by a low parapet wall.

At the east end of the mound are placed the four arches with their sluices, by which the water of Fleet and occasional land-floods pass to the sea at low-water; but the sluices being each twelve feet wide, they cannot be commanded without machinery, which has therefore been provided and affixed.

Several acres of land immediately above the bridge are always under water; but towards the upper end of the Strath and the western side of it, wherever any water descends from the side of the hills, a considerable degree of vegetation has begun to appear, and annually increases. The arches required greater solidity of foundation than was provided by the original estimate, and afterwards rock-cutting was found necessary to admit the current of water to run direct upon the sluices, which are now defended by a row of piles against large masses of floating ice.

Estimate	£. 8,435	–
	+ 304	7
	+ 550	3
	£ 9,289	11
Expenditure	9,289	11

£. 644 - -
78 - -
£. 722 - -

Additional estimates to the amount of £. 855 were undertaken by the contractors, besides which, the Marquis of Stafford indemnified their loss on the original contract to the amount of £. 644, and built a cottage for the use of the flood-gate keeper, at the expense of £. 78. Altogether, the entire expense of the Fleet mound and of the roads of approach to it cannot have been less than £. 12,500, of which the public paid no more than £. 4,700.

Measurement. Miles. 21 Yards. 880
Expenditure - £. 6,897. 18.

DUNROBIN ROAD.—From Strath-Fleet the road approaches the coast near Golspie Church; it then turns to the left, passing behind Dunrobin Castle, and again, at the old bridge of Brora, approaches the coast, from which afterwards it does not greatly recede, though in some places it is carried along the base of the mountains at the upper boundary of the arable ground. This road terminates on the Ord Hill, where the Caithness roads commence, and is, generally speaking, solid and durable, but is said to suffer materially from a cause which we cannot deprecate, nor wish to dissemble; that is, from the increase of laden wheel carriages of a superior kind, consequent on the improved cultivation of this part of the coast of Sutherland. The Helmsdale bridge was built under a distinct contract.

All the roads from Bonar Bridge to the Ord, entitled, in the aggregate, the Sutherland Coast Road, are maintained in repair under one contract, the expense of which has been £. 939 in the last four years, averaging at £. 5 per mile per annum, not including the expense which has been incurred in the improvement of the Skibo road; and we wish that our own funds and those of the county were such as to enable us to look forward to a larger addition of hard materials on the whole of the Sutherland Coast Road.

Measurement. Miles. 34 Yards. 890
Expenditure - £. 14,448. 8. 6.

DUNBEATH ROAD.—The Dunbeath Road is the next in succession; it is more solid, and in other respects not inferior to the last-mentioned road. It passes along the coast throughout its whole extent, and terminates at the town of Wick, where, and at Pulteney Town, an immense herring fishery is now established by means of the new harbour. The expense of repairing this road during the last four years has amounted to the sum of £. 523, averaging at £. 3. 10*s.* per mile per annum; but the expense must be increased. The bridge at Latheran Wheel is not inconsiderable.

Measurement. Miles. 20 Yards. 475

THURSO ROAD.—The estimate of the intended road from the town of Wick to the town of Thurso appeared to us to be unaccountably high, and yet was so much lower than any offer of contract, that we thought it our duty to signify to the heritors of Caithness, who had applied for this road, and deposited a moiety of the estimated expense, that they must absolutely undertake to make the road themselves, or relinquish it altogether. They undertook the contract, therefore, engaging, for £. 12,610, to perform what had been estimated at £. 10,444, and actually paid to their sub-contractors £. 12,072. 19*s.* 10*d.*; and we, having caused particular attention to be given to the mode of proceeding, have no cause to think that any unusual degree of

improvident expenditure has been incurred, but rather the contrary: notwithstanding which, the heritors of Caithness have represented in a memorial, and indeed satisfied us, that by reason of a failure in the materials at first applied on part of the road, they have been under a necessity of replacing the surface at an expense little short of £. 1,300, (at the instance of our inspector), and that the entire expenditure on the Thurso road has amounted to £. 13,365, being £. 2,921 above the original estimate; for one moiety of which excess we cannot but hold ourselves (on the part of the public) to be debtors to the heritors of the county of Caithness, who did not undertake this contract voluntarily, but relying on equitable consideration, provided our opinion that the road might be made at the estimated expense should prove to have been ill founded.

Estimate	-	£. 10,444	7	8
Expenditure	-	13,364	17	11
Excess	-	£. 2,920	10	3

The road was finally inspected and taken off the hands of the contractors in July 1819, and we are sorry to find that some part of it still shews symptoms of infirmity, the broken rock, with which the road is metalled, proving to be of a rotten nature, speedily destructible by wear and by the weather; so that considerable labour in renovation of the surface must, we fear, be anticipated, especially as the expense incurred on this road in 1820 (its first year) amounted to £. 7 per mile.

At Greystones, midway between Wick and Thurso, is a considerable arch over the water of Wick.

Highland Mail Coach.—Having had occasion incidentally to mention the coach which conveys the mail between Inverness and Thurso on the roads which we have been describing, we cannot avoid stating succinctly, that in July 1819, about the time when the Road Repair Act of that year received the Royal Assent, a mail coach was established for two years certain, the northern counties agreeing to indemnify, to a certain extent, any eventual loss which might otherwise fall on the proprietors of the new establishment; and we learn with satisfaction the success of this experiment, insomuch that the heritors have lately agreed, almost unanimously, to continue this allowance or indemnification during a further term of five years.

It is not to be understood that this northern mail coach (or diligence, as it is usually called) is exactly the same thing in form or speed as those of the southern parts of the kingdom, but it appears to be well calculated for its purpose. It carries three inside passengers (one of them looking backward), three outside passengers, the driver, the guard, the mail, and other luggage. The coach itself is lighter by two or three hundred weight than a southern mail-coach, and the speed required is no more than six miles per hour; but it is drawn by two horses in place of four, and these horses generally, their provender always, of an inferior kind.

This coach, starting from Inverness daily at six o'clock in the morning, arrives at Thurso (on the north coast) between eleven and twelve the next

day; and, returning every evening from Thurso at seven o'clock, arrives at Inverness between twelve and one, performing (as it is termed) one hundred and fifty-nine miles each way with this modest apparatus, and twelve changes of horses.

It would be unreasonable to expect that occasional snow-storms and sudden thaws, added to the general influence of a humid climate, and (more than any of those causes) the inexperience and want of accurate habits in the persons engaged in such an undertaking, should not sometimes delay the arrival of the coach beyond its stated time; but probably tacit allowance is made for such accidents, as we do not find that the mail-coach has ever returned to Inverness so late as to retard the conveyance of its letter-bags southward.

The northern mail-coach quits the Parliamentary roads for a space of seventeen miles in going to Tain, and about six miles for the sake of passing through Dornoch; the remaining one hundred and thirty-six miles of road were made under the Highland Road and Bridge Commission, excepting eight miles on this side of Dingwall, lately repaired and improved under our care, as already mentioned; and however impossible it is for us to entertain an unfavourable disposition towards a mode of intercourse, the most striking result of our labours, we must be admitted to observe, that if the wear of a road may fairly be measured by the amount of the turnpike tolls usually paid in Scotland, this mail-coach must be supposed to add largely to the expense of road repair; to what amount cannot be determined, but we are assured that such a carriage would have to pay in tolls no less than £.760 per annum; and we have had occasion, in a former part of this Report, to state, that the Parliamentary roads are not composed of such materials as can bear with impunity daily use to that extent; the maintenance of the road between Inverness and Thurso has hitherto cost about £.5 per mile, or £.800; and we are not enabled to go beyond £.6 per mile, which we fear will prove to be a scanty expenditure, especially on the Thurso road, where hard materials cannot be procured; and we do not scruple to state in general terms, that although the surface of the roads made or improved under our care (which we have stated at eleven hundred and eighty-three miles) is always smooth, never molesting the traveller by a single jolt,—yet in the winter season it is somewhat penetrable and soft in places where proper materials could not be obtained at all, or not for the rate of expense to which our surveyors and contractors were restricted.

Measurement.	
Miles.	Yards.
47	1,672

TONGUE ROAD.—The Tongue road is named from an inlet of the sea, where it terminates on the north coast of Sutherland. The southern extremity of this road is at Bonar bridge, from which place passing along the north side of the Dornoch Frith to the river Shin, it ascends to Loch Shin, and then proceeds up Strath-Tarrie till it attains its summit, at a place called the Crask. In its descent to the northward, after touching upon Loch Naver, it penetrates Lord Reay's country, near Loch Layghall or Loyall, and reaches the North Sea at Tongue, thus entirely dividing the county by a line almost fifty miles in

length. The importance of this road to the heritors of Sutherland is sufficiently obvious, and the previous surveys were numerous. Mr. George Brown, Mr. David Wilson, Mr. Fulton and Mr. Mitchell were employed on it at different times, and so persevering were conflicting opinions, that when at last the contract was undertaken by Mr. Gilchrist, in March 1815, it was understood to be liable in one part to subsequent decisions, by which in fact the line was varied at the Crask, and the contract price increased from £.15,770 to £.16,000. Mr. Gilchrist proceeded with energy during the years 1815 and 1816; thenceforth he relaxed in his exertions; but after a voluminous correspondence and many painful inspections,—in the course of which accusations of having manifested undue favour and undue severity were thrown out by the contending parties against Mr. Mitchell and Mr. Hope,—the road was finally inspected in August last, and taken off the hands of the contractor with the approbation of Lord Reay's family, and indeed of all parties concerned; the accounts having since been passed at a county meeting holden for that purpose. From this narrative will be understood some part of the difficulty which has embarrassed our proceedings in making this road; but the value of it is worth all that it has cost of money and of uneasiness.

The comparison of the expenditure with the estimate or estimates is difficult, from the variations which have been mentioned. The estimate annexed to Mr. Fulton's survey, of a circuitous route indeed, amounts to £.21,865; D. Wilson's estimate to £.15,186, and one obtained in 1805 to no more than £.6,492. We state all these chiefly for the sake of shewing that none of them could be relied on, and that we were compelled to relax from ordinary rules, or to forego the opportunity of accomplishing this important road.

For the purpose of saving expense, the breadth of the gravelled road was reduced from fifteen to twelve feet; but at the south end it was afterwards widened. An additional piece of road at Tongue was consented to, and another piece already made there was superseded. A long drain on the flat morass near the Crask was found to be necessary; a quantity of sharp gravel from the bed of the river Tarrie was laid on part of the road, and rock was cut and removed, and additional bulwarks built near Aultnacharra bridge. By these additions, the contract price was raised to £.16,635, and again lowered by deficiencies to £.16,552.

	£.	s.	d.
	200	-	-
	100	-	-
	22	-	-
	26	4	6
	260	-	-
	13	4	-
	13	4	-
	16,000	-	-
	£. 16,634	12	6
	82	10	-
Expenditure	£. 16,552	2	6

The contractor was indulged, and the neighbourhood accommodated, by taking off his hands the north and south ends of the road to the extent of twenty-nine miles, and he was allowed £.279, or £.4. 16s. per mile, for keeping this portion in due repair during two years; the narrowness of any road increasing the expense of maintaining its surface in a proper form.

Alford Road.—Far remote from the Northern Highlands is the Alford road, which, after excellent bridges had been made over the rivers Dee and Don, seemed to have an irresistible claim to our notice, as connecting these two rivers, five-and-twenty miles west of Aberdeen. The direction of the Alford

Measurement.

Miles.	Yards.
13	989

road is north and south; the final inspection of it took place in September 1817, when, from a mistake in laying gravel on part of the road instead of broken stone, the contractor was found liable to a deduction from the contract price. But the contributors were so well satisfied with his conduct, and convinced that little or no profit had accrued to him, that they agreed to pay the contract price in full, provided the same was done on our part;—and this was readily acceded to, a saving on the estimated expense still remaining in hand.

Estimate -	£. 4,088 15 7
Expenditure	4,020 - -
Saving - -	£. 68 15 7

The expense incurred in repairing this road during the last three years has amounted to £. 137, averaging at £. 3. 8*s.* per mile per annum.

BRIDGES.

Several bridges which have been built under distinct contracts, and which do not, strictly speaking, form part of any of the Parliamentary roads, must next be noticed; these are ten in number, on which has been expended the sum of £. 65,000; and besides these bridges, several others have been built superior in dimensions to some of them, although originally included in the contracts for making the roads of which respectively they form an essential part.

The nature of the surface, and of the climate in the Highlands, renders indispensable a vast number of apertures under every road, insomuch that those water-courses which have required one or more arches to be placed over them, exceed in number eleven hundred in eight hundred and eighty miles of road. We have subjoined in the Appendix a brief Statement of the extent of these bridges.

Water-way. 446 feet.

Dunkeld Bridge.—This bridge, which has superseded the ancient ferry over the river Tay at Dunkeld, is a magnificent edifice in the span of its middle arches, and altogether worthy of the grandeur of its situation. The amount of money expended on it, and in opening and forming suitable approaches, is supposed to have exceeded £. 30,000; the larger portion of which was defrayed by his Grace the Duke of Athol, in expectation of a partial remuneration from tolls. The residue expense (to the amount of £. 14,000) has been paid; one moiety by the public, the other by the Duke, who, to the extent of £. 7,000, became a contributor under the provisions of the Highland Road and Bridge Act. A considerable object was thus attained, Dunkeld being, as it were, the portal of the central Highlands, and more remotely the access to all the northern roads.

Expenditure - £. 14,054 - -

£. 500 - -
194 - -
£. 694 - -

The removal of a house was necessary for direct access to the bridge, and this has cost £. 500, which payment, with interest due thereupon, closed our transactions at Dunkeld.

Dalnacardoch Road.

We are now enabled to state, and with much satisfaction, that, under an Act passed in the last Session of Parliament, the road from Dunkeld to the confines of Inverness-shire, a distance of forty miles, will soon be in good con-

dition. One-third of it, and that the northern part, was finished in the last autumn, and the Duke of Atholl is proceeding steadily, and not without some intention of improving the direction of the line of road, which is one of those originally made for military purposes in the middle of the last century. From Dunkeld, this road passes by Blair-Atholl and Dalnacardoch, and entering Inverness-shire, it separates into two roads at Dalwhinnie; one of them directed northward to the river Spey and through Badenoch to Inverness; the other crosses the Laggan road, and then passes over the Corriarick mountain to Fort Augustus, which road is maintained in repair as a good cattle road, though steep and tedious for wheel carriages.

At Inverness, which may be deemed the metropolis of the Highlands, are two bridges over the river Ness, beyond which, at ten miles distance, the river Beauley is crossed by means of the bridge next to be mentioned.

Lovat Bridge.—The late Fraser of Lovat having advanced a moicty of the expense of building a bridge at this place, it is named from his title, and is beautifully situated in full view of Beaufort Castle. It is a considerable bridge, of five arches, the middle arch spanning sixty feet, the others fifty feet and forty feet respectively. On this bridge has been expended about £.40 for pointing with mortar and for repairs of the road-way, during the last four years.

Water-way. 240 feet.
Expenditure - £. 8,802 -

Conan Bridge.—Ten miles beyond the Beauley river and its bridge, the river Conan is now crossed by a bridge instead of an ancient ferry. The Conan bridge is also of five arches, and of larger dimensions, being sixty-five, fifty-five and forty-five feet respectively; this excellent bridge was placed between two pieces of bad road, lately much improved; and the town of Dingwall is now approachable from the south without inconvenience.

Water-way. 265 feet.
Expenditure - £. 6,854 -

Bonar Bridge.—From Dingwall the Fearn road extends to the northern limit of Ross-shire, where the Dornoch Frith used to prohibit access to Sutherland and Caithness, unless by means of an inconvenient and dangerous ferry. Various were the schemes proposed for improving the Mickle Ferry, by removing it to Creech or elsewhere; but these were superseded by a bold resolution of the heritors of the county of Sutherland, to contribute towards throwing a bridge over the frith at Bonar; and this was effected in the year 1812. It consists of an iron arch, one hundred and fifty feet in span, and two stone arches of sixty and fifty feet respectively. In the year 1814 the iron arch sustained, without damage to itself, a tremendous blow from an irregular mass of fir-tree logs consolidated by ice; and in the year 1818 it underwent the same sort of probation at its other side; for being situated at a narrow part of the frith where the tide flows with great rapidity, a schooner was drifted under the bridge, and suffered the loss of her two masts, the iron arch remaining uninjured.

Water-way. 260 feet.
Expenditure - £. 13,971 - -

The Bonar bridge cost not much less than £. 14,000, great expense having been incurred in the foundation of its piers and abutments. The iron-work was well painted in the year 1819, at an expense of £. 130.

We have already had occasion to describe the FLEET MOUND, by which the Little Ferry is superseded.

Water-way. 156 feet.
Expenditure - £. 2,000

WICK BRIDGE.—At the town of Wick in Caithness, and over a river of the same name (near the junction of the Dunbeath and Thurso roads) is a considerable bridge of three arches; it was finished in the year 1809, and is connected by a short piece of road with the harbour, where a new town called Pulteney Town has sprung up on the south side of the river, not within the municipal jurisdiction of the Burgh of Wick. Here ends our northern line of bridges.

Water-way. 195 feet.
Expenditure - £. 8,200

CRAIGELLACHIE BRIDGE.—The bridge over the river Spey at Fochabers was built by the Duke of Gordon about seventeen years since, partly at the expense of the public, and is maintained by tolls, not differing materially in the circumstances of its erection from Dunkeld bridge, excepting that it was not completed under our care. The utility of it was so strongly felt in the neighbourhood, that an application was made in the year 1810 for aid towards building a second bridge over the Spey at Boharm; but this being within six miles of Fochabers, we did not hold out much encouragement to the memorialists. Aware of the nature of our objection, they fixed on another site twelve miles above Fochabers, where the river Spey, rushing obliquely against the lofty rock of Craigellachie, has cut for itself a deep channel, not exceeding fifty yards in breadth. Over this an iron arch has been constructed, and is the more beautiful, from not being in immediate contact with masonry arches, as was necessary at Bonar. The scattered birch trees and native firs on the side of the impending mountain, the meadows along the valley of the Spey, and the western road of access to the bridge cut deeply into the face of the rock, combine, with the slender appearance of the iron arch, in rendering this spot one of the most remarkable in Scotland.

Subsidiary to the main arch, and at some distance from it, are three others, built of stone, fifteen feet span each, under the eastern road of approach. These are useful in time of speats or river-floods, to which the Spey is remarkably liable. The entire price of this bridge, and its approaches, including the rock-blasting on the west side of the river, was no more than £. 8,200; but we have to regret that the contractors, in their zeal for the speedy and effectual accomplishment of their engagement, lost about £. 500 additional. This bridge was painted in 1818 at an expense of £. 130; and for parapets and railing along the eastern causeway of approach was expended above £. 100 last year.

Water-way. 238 feet.
Expenditure - £. 4,224

BALLATER BRIDGE.—Next after the rivers Tay and Spey, the river Dee is supposed to be the largest in Scotland, and was very insufficiently furnished

with bridges, there being no more than one between Braemar and Aberdeen, a space of fifty miles. At Ballater a bridge had indeed been built in the year 1783, but being of inadequate dimensions and solidity, it was destroyed by a river-flood in the year 1799. We undertook with great readiness to replace it, contributions from all classes of the neighbouring population proving how severely the loss was felt. The new bridge was finished at the end of the year 1811; it is of large dimensions, the middle arch of five being sixty feet in span.

The inconsiderate manner of floating timber logs from the Forest of Mar whenever the river is unusually swollen has oftener than once endangered this bridge; and an Act was passed in 1813, at our suggestion, for the protection of bridges in Scotland, by rendering the offender liable for any injury sustained. The roads of approach to Ballater bridge are of some extent, and, with the bridge, usually cost £.20 per annum in repairs.

Water-way. 200 feet.
Expenditure - £.4,067

POTARCH BRIDGE.—About seventeen miles below Ballater, was found a situation so well adapted for another bridge over the river Dee, that the increased stream required a bridge not so long as that at Ballater. Near Kincardine O'Neill, the river has worn itself a passage through the solid rock, leaving prominent a singular mass of porphyry near the middle of its channel, and on this the principal pier of Potarch bridge was securely founded at a moderate expense.

An expensive accident befel the contractor, whose timber-framed centerings, with part of the unfinished arches, were demolished by floating timber; and this operated as the greater hardship, inasmuch as he had undertaken the contract at a low price. He proceeded, however, with great energy in repairing the damage, and completed the bridge in the summer of 1814. It is of three arches, the middle arch being seventy feet in span, the other two sixty-five feet each.

Water-way. 128 feet.
Expenditure - £.2,000

ALFORD BRIDGE.—Fourteen miles distant from Potarch, to the northward, the river Don runs parallel with the river Dee, and equally intercepts communication, the ferry or boat (as it was called) of Forbes affording very imperfect accommodation. At this place was found a convenient situation for the Alford bridge, which was finished in the year 1811. It is of three arches, the middle arch spanning forty-eight feet, the others forty.

An excellent road (already described) connects the bridges of Alford and Potarch, and serves as a very useful model of road-making in a country far distant from any other of the Parliamentary roads.

Water-way. 127 feet.
Expenditure - £.1,255

FAIRN-NESS BRIDGE.—From the Fairn-ness bridge originated the western branch of the Findhorn road, already described. This bridge is chiefly founded on a rock, almost as conveniently situated in the bed of the river as that mentioned at Potarch. It was finished in the year 1816, at an expense of £.1,250, of which sum Sir James Montgomery Cuninghame paid more

than a moiety. The middle arch is of fifty-five feet span, the other two of thirty-six.

Losses of Contractors.

We have yet one painful duty to perform before we conclude our Report of Highland Roads and Bridges. In the course of our transactions it has happened that many of the contractors have suffered considerable loss; some to such an extent as completely to exhaust their own resources, and further to involve their cautioners or sureties to a large amount. As a general principle, it cannot be denied that, as the contracts were voluntary, eventual loss ought to fall on the party to whom the gain, if any, would have accrued; and it is also certain that these losses have in many instances been owing to the negligence and unskilfulness of the contractors; perhaps even (in some few) from a culpable determination to undertake the work at any price for the chance of gain, although they were conscious of their own inability to make good deficiencies, should any arise. But after all these allowances, cases of great distress and real hardship have occurred: the new roads were deservedly popular, and men of enterprise were laudably desirous of distinguishing themselves by partaking in the execution of them. Moreover, the specifications of our contracts were strict, and unusual in the Highlands, insomuch that the estimates of the surveyors were at first as inadequate as the contract prices. Consequently a large portion of the difficulties and embarrassments which subsequently occurred were unforeseen, and therefore unprovided against.

So much may fairly be said for the contractors; for those who have suffered as cautioners or sureties, it may be further urged, that they sometimes became responsible lest works might be retarded in which they had no individual interest, and from being engaged as sureties it is evident they could not derive any personal profit whatever; while at the same time they were necessarily one remove farther from the means of obtaining accurate information.

Under all these circumstances various memorials have been successively transmitted from Scotland, praying some compensation for losses incurred. Of such memorials we found it necessary to postpone the consideration until the end of our transactions should enable us to form a judgment of the full amount of the loss; and we now find, not without deep regret, that the very extent of the evil precludes us from giving any hope of relief; the unavoidable losses of sureties, contractors, and the creditors of those contractors, being estimated at £. 34,000, and their actual loss having been probably twice that sum.

Thus ends our Report of Highland Roads and Bridges; but having been appointed by various Acts of Parliament to superintend certain extensive improvements on the road between Glasgow and Carlisle, and (more recently) the making of two considerable roads in Lanarkshire, we must extend our Report accordingly.

GLASGOW AND CARLISLE ROAD.—In our Report of 1817, we stated that an Act had passed in the preceding year, granting £. 50,000 towards the improvement of a large proportion of the road between Glasgow and Carlisle; and that we were appointed to superintend the application of this money, which was intended to produce an equal sum by contributions of the parties interested, such being the condition of the grant; the grounds of which are explained in the previous Report of a Select Committee of the House of Commons.

The entire extent of the road from Glasgow to Carlisle was about one hundred and two miles, from which distance the contemplated improvements went to subtract eight or nine miles; and having caused a particular plan and estimate to be made of such parts of it as were most in need of improvement, we directed our earliest attention to the mountainous district (thirty miles distant from Glasgow) between Douglas mill and the village of Abington, a distance of about nine miles; and as soon as a moiety of the estimated expense had been provided in terms of the Act, this portion was advertised for contract, and has since been substantially executed at a price considerably below the estimate. This road has been in use during two seasons, and is now consolidated and smooth. There is one arch of sixty feet span, and ten of smaller dimensions, in this improved portion of the Glasgow road.

Expenditure:

Road	-	£. 5,059
Bridges	-	1,318
Total	-	£. 6,377

From Abington (southward) to the distance of Moffat in Dumfries-shire, the old road was in a good state, and the next improvement commences at the point where the Edinburgh road to Dumfries crosses the Glasgow and Carlisle road at Beattock, about sixty miles from Glasgow. The new portion of road passes down the western side of the river Annan, and, crossing it at Johnstone Mill, again joins the old road near Dinwoodie, being a distance of eight miles and a half. This road contains an arch of eighty feet span, another of forty-five feet, and eight others; it is sufficiently level throughout, and so direct as to save two miles and a half in distance.

Expenditure:

Road	-	£. 4,445	-
Bridges	-	3,665	-
Total	-	£. 8,110	-

The improvement of the districts, which, if not mountainous, are on very high ground, having been thus accomplished, Douglas mill before mentioned became the southern limit of a new line of road passing near Lesmahago to Kirkmuirhill, about eight miles in length; and containing four considerable bridges, one of three arches across a deep dingle, and seventy feet in height. This contract has been completed in a perfect manner, and the new road is in use. A toll-house has been erected at Lesmahago.

Expenditure:

Road	-	£. 7,140	-	-
Bridges	-	3,600	-	-
Total	-	£. 10,740	-	-

Hitherto the sundry works had been let by public advertisement, the lowest offer accompanied by satisfactory security having been always preferred; but the manufacturing population in and around Hamilton having become clamorous for employment, the Duke and some others were induced, in October 1819, to offer to undertake a portion of road near that place; and the case being too urgent to admit of advertisement, they became contractors at twenty per cent. below the estimated expense, being the computed rate of saving upon the foregoing lots. This portion of road, which is four miles and

Expenditure - £. 4,628 - - a half in extent, is finished in a satisfactory manner, and in full use. Nearer to the town of Hamilton the road is in a good state of repair; and the bridge over the river Avon is now rebuilt.

58° Geo. III. c. 44. L & P.
59° Geo. III. c. 90. L. & P.

From the river Sark (which forms the boundary between Scotland and England) to Carlisle is eight miles, and a new road is nearly completed, which will save four miles in distance on the Port Patrick as well as on the Glasgow road, and for this reason was provided for on very favourable terms by a particular Act of Parliament, whereby a sum of £. 22,000 (part of the before-mentioned £. 50,000) was made applicable thereto without answerable contribution by individuals interested. There are two large bridges in this piece of road, one of two arches over the river Sark, the other of three arches over the Esk; these last are of cast-iron, one of them of a hundred and fifty feet, two others of a hundred and five feet in span each.

Expenditure:
Road - £. 9,062
Bridge - 11,232
£. 20,294 - -

The northern part of the new road at this place tends to the westward more than is requisite for the purpose of the Glasgow road, thereby shortening the turnpike road to Dumfries and Port Patrick, the trustees of which have given ample security to defray any additional expense, and the contract is completed.

Having thus reported our transactions under the Glasgow Road Act in order of time, it is necessary for the sake of distinctness to recur to situation also, commencing at the city of Glasgow; from whence to Hamilton (eleven miles) has been improved by the turnpike trustees; herein Bothwell bridge near Hamilton remains narrow, considering its length and importance, but the southern access to it has been facilitated by cutting and embankments.
Miles. One mile from Hamilton southward, the road crosses the river Avon, and from
4 ½ this place the Duke of Hamilton's contract extends over four miles and a half. An unimproved portion of road (three miles) succeeds, and at twenty miles
8 from Glasgow commences the Lesmahago improvement, eight miles in extent; the old line of road remains unaltered at Douglas Mill for nearly two miles;
9 then succeeds a new line of nine miles skilfully traced over the high ground, from that place to Abington on the river Clyde; thence the old road southward adheres to the course of the Clyde by Crawford to Elvan-foot; thence ascending to the sources of the Evan water, it passes along the Glen Evan, till in the neighbourhood of Moffat, twenty miles from Abington, another improvement
8 ½ commences with Beattock bridge, and extends eight miles and a half to Dinwoodie Green, accompanying the river Annan, and crossing it at Johnstone Mill, where a good inn has been built. From Dinwoodie Green to Gretna (twenty miles), five more new bridges have now been built; viz. one over the Milke-water near Lockerbie; one over the Mier near Ecclefechan; one over the Kirtle near Bonshaw; one over the Clyde near Elvan-foot; one over the Avon near Hamilton; considerable and general improvement has been
9 applied; from Gretna to Carlisle, nine miles of road, called "The Cumberland
39 Section," is a new line, shorter by four miles in thirteen, as compared to the

old road: in all, the new road is thirty-nine miles in extent, and will cost, with its bridges, upwards of £. 50,000; an amount which proves the impossibility of making metalled roads in the Highlands, where, fortunately, such expense is not advisable,—as has been already explained.

The road and bridge contracts have been undertaken and completed much under the estimated expense; but the land necessary to be acquired was expensive far beyond expectation, so that a considerable sum of money has been thereby diverted from its more appropriate application.

The perfect execution of all the contracts is chiefly attributable to the practical skill and unwearied zeal of Mr. John Pollok, who has superintended the whole in a manner which cannot but highly recommend him for employment on any similar occasion of making or improving first-rate roads, in which class may safely be ranked the portions of Glasgow road made under his care.

Lanarkshire Roads.—Early in the year 1820, the want of employment for the manufacturing population in Lanarkshire induced the heritors of that county to apply to his Majesty's government for a loan of Exchequer Bills on better terms than was permitted by the Act of 1819; and this favour having been conceded upon the urgency of their representations of general distress, they proceeded to obtain an Act of Parliament, authorizing them, upon raising one-third of the estimated expense, to make two roads, crossing each other in the upper part of the county; and we, as having been appointed by the Act to superintend the effectual execution of its provisions, and having received pressing statements of the necessity of providing immediate employment, proceeded, accordingly, in directing Mr. Telford to prepare the necessary plans, specifications and estimates without delay; and he seconded our intentions in the manner we had reason to expect of him, by hastening to Lanarkshire with proper assistants, and by not leaving the county until, after six weeks of incessant labour, his task was completed, the limits of the proposed contracts having been determined, the line of new road marked on the ground, and all documents necessary to enable the heritors to proceed in depositing their requisite contribution of one-third, having been lodged with Mr. Hope, our law agent at Edinburgh, through whom a large sum of money, produced by selling part of the £. 51,475 Exchequer Bills, had already been transmitted to the Bank of Scotland.

The north and south line of road commences at Cumbernauld, above the northern border of the county, and, passing near Airdrie, proceeds through Carluke and Lanark, and, crossing the Clyde at Hyndford bridge, terminates at Abington, where it forms a junction with the Glasgow road. The length of this proposed road is forty-one miles, and opens a communication from the cattle markets of Crieff, Down and Falkirk to Carlisle, and farther south.

The east and west line of road commencing at Briech-water (the termination of a new road from Edinburgh) proceeds thence by Allanton to Cambus-

nethan, where it crosses the north and south line of road; afterwards it crosses the Clyde at Garion bridge, and the new Glasgow road at Stonehouse, and, passing through Strathaven, terminates at Loudon Hill; thus stretching twenty-four miles from the eastern to the western boundary of Lanarkshire.

Roads	£. 14,292
Bridges	- 4,425
	£. 18,717

In the upper ward of the county the heritors had satisfied the liberal terms of the Act by part of the north and south road recently made, the expense of which thus became further available, and ten miles in addition to their eight miles is under contract, including a lofty bridge over the dingle of Cartland Craigs, near Lanark. It is of three arches, and its centre arch is one hundred and twenty-two feet in height. (*See* Plate 54.)

HARBOURS.

In the year 1806, a Select Committee was appointed by the House of Commons to examine 'the Accounts of Grants already made payable out of the funds arising from the forfeited estates in Scotland, and of the balances arising therefrom.'

It is almost needless to say that these estates were forfeited in consequence of the events of the year 1745, and were restored to the heirs of the former proprietors in the year 1784, on conditions which left a considerable sum of money applicable to public purposes in Scotland.

This fund remained under the care of the Court of Exchequer in Scotland, subject to the disposition of Parliament, and had been largely applied to various purposes, when the Committee took into consideration the disposal of the balances then remaining; and on their suggestion further grants having been made by Parliament in July 1806, the residue was placed under our management, applicable to harbours and similar improvements in Scotland.

In present money this residue was found to amount to no more than £.13,000, besides which a sum was retained at the Exchequer; and a further sum of £.25,000 was due from the City of Edinburgh, secured upon the Leith Harbour dues; but this was burdened with an annuity of £.800 payable to the Highland Society during ten years, which expired therefore in the year 1816; and before the end of the next year, 1817, the City of Edinburgh, finding means to borrow money from parties not likely to call soon for the principal, paid off the entire Leith Harbour debt; after which we were not slow in extinguishing (on a fair valuation) three small annuities charged on the sum remaining at the Exchequer; so that upon payment of £.846 the whole fell into our hands. There is indeed a debt of £.25,000 due from the Crinan Canal, and an obsolete claim on the Perth estate, neither of them of any convertible value. In the whole we have realized £.52,000; all which having been disposed of, we shall recount in a summary manner what has already been reported from time to time, and conclude with our recent transactions down to the present date.

Burgh-head Harbour.—This small harbour on the Moray coast is sheltered towards the east by the promontory of Burgh-head, famous for its supposed Roman station. A company of proprietors had already expended £.6,000 under such circumstances as justified us in granting them £.2,000 for completion of the work. The new basin is two hundred yards by fifty yards, forming a small tide harbour fit for the coasting trade, and much in use for the export of grain.

Frazerburgh Harbour.—Eastward of Burgh-head, at fifty miles distance, is Kinnaird's Head; close to which is the town of Frazerburgh, possessing a harbour which hitherto had been but slightly sheltered by distant rocks and imperfect piers. Several plans of improvement had been formed, and one of them was in progress when application was made to us for aid, which was readily granted to the extent of £.5,220, an equal sum being raised by the inhabitants of the town and their patron. An additional sum of £.400 was afterwards granted towards lengthening the projecting pier fifty feet, and the result is, that from low-water mark it extends four hundred and forty feet into the sea, where a return pier of one hundred and fifty feet affords shelter from easterly winds. We understand this to have given so much satisfaction, that a further improvement has been since effected at the expense of the inhabitants, and of Lord Saltoun.

Expenditure.	
£. 5,220	- -
5,220	- -
400	- -
400	-
£. 11,240	- -

Peterhead Harbour.—The flourishing town of Peterhead is situate on the coast of Aberdeenshire, and occupies a more eastern position than any other place in Scotland. A rocky island now joined to the shore and called the Green Hill forms a north and south harbour; the latter has hitherto been in use, and towards deepening this, and extending the western pier, we granted a moiety of £.7,800, the harbour trustees raising the other moiety, and also £.2,076, which with the above sum had all been usefully expended on the South Harbour in the year 1811.

Joint Expenditure on the South Harbour.	
£. 3,900	- -
3,900	- -
£. 7,800	- -

The ground on which the town stands belongs in property to the Merchants' Maiden Hospital at Edinburgh, and the trustees then began to turn their attention to the Northern Harbour, by the improvement of which they hoped not only to obtain deeper water, and to double their sheltered space, but also to insure an easy entrance into one of the two harbours from whatever quarter the wind might blow. With this intention they raised £.10,000, and applied to us for aid to the like amount, which we were enabled to grant in the year 1818.

The protecting pier extends four hundred and seventy feet in a line directly northward from the high-water mark of the Green Hill before mentioned; half that distance into the sea from the low-water mark, the inside wall being founded on caissons; and the curved end of the pier extends towards the north-west eighty feet, founded also on caissons ten feet under low-water mark, which with the usual rise of tide is sufficient for the entrance of the largest vessels employed in the Greenland fishery.

Joint Expenditure on the North Harbour.
£. 10,000 - -
10,000 - -
1,700 - -
1,700 - -
£ 23,400 - -

The solidity and construction of this pier were such as the exposure of the situation seemed to require; but the violent storm which happened on the 23d and 24th of October 1819, overthrew so much of the unfinished masonry that the damage was estimated at £.3,400; one-half of which the trustees offered to contribute, but were unable to take the whole upon themselves. In this emergency they again applied to us, and subsequently to Parliament, without success, and thus (all other means failing) we were at last constrained to appropriate to the restoration of the Peterhead pier, and that of Banff (which had suffered in like manner) certain sums already assigned to other improvements, but not definitively accepted by the contribution of equal sums.

The basis of the new pier at Peterhead has been widened by the mode of reparation adopted, and its power of resistance proportionally increased. It is nearly finished, as is also the deepening of the North Harbour and the wharf wall at the root of the pier. A spacious graving dock is included in the same estimate and contract, as a concomitant improvement for the completion of the new harbour.

Expenditure.
£. 1,972 -
1,972 -
£. 3,944 - -

KIRKWALL BAY.—At Kirkwall, the principal town and place of resort among the Orkney Islands, the bay or roadstead was considerably open towards the north, insomuch that communication between the shore and the shipping was impeded when the wind blew from that quarter. For remedy of this inconvenience, a pier has been constructed, which projects one hundred and twenty yards from the shore, and there becomes what is called a return pier, one hundred feet in length, and by pointing to the north-west it insures still water, and is said 'to serve every purpose in the loading and unloading of vessels 'that was expected or requisite.'

Expenditure.
£. 864 - -
864 - -
£. 1,728 - -

TARBET HARBOUR.—The remarkable *Tarbet* or Carrying-place, where Cantyre is separated from the other districts of Argyllshire, does not exceed one mile and a half in breadth, and on the east side of this isthmus a small harbour has been rendered commodious by a quay or wharf wall, and by shaping a small insulated rock into a station for capstern apparatus. A bridge and road of approach to the quay completes the accommodation now afforded. It was finished in August 1813.

Expenditure.
£. 2,008 - -
2,008 - -
£. 4,016 - -

FORTROSE HARBOUR.—The Burgh of Fortrose is situate at the eastern extremity of the Black Isle road, on the north side of the entrance of the Beauley Frith. The expectation of extensive utility from the formation of a sheltered harbour appeared so well founded, that we readily engaged to afford the usual aid. The estimate was increased from £. 3,500 to £. 4,000 by the addition of forty feet to the extent of the return pier, whereby the water at the entrance of the harbour became a yard deeper, and the spring-tides rising fourteen feet, access is given to vessels of considerable burden. The inside of the harbour is about thirty yards square, and three sides of it form an extensive wharf. It was finished in October 1817, and we understand it to have fulfilled the expectations of the contributors.

Avoch Harbour.—Avoch, a well known fishery station, is two miles westward of Fortrose, on the same shore. Sir Alexander Mackenzie, the proprietor, applied on behalf of the inhabitants for a landing pier; and this, or rather a small harbour, has been built, extending ninety yards from the Black-Isle road, which at this place passes along the shore. By means of an obtuse angle at two-thirds of its extent, the pier becomes a complete shelter towards the south-west, and, with a break-water to the eastward, forms a safe harbour for coasters and fishing boats. It was finished in April 1815.

Expenditure.		
£. 528	-	-
528	-	-
£. 1,056	-	-

Portmaholmach Pier.—Within Tarbet Ness (the remarkable head-land of the Dornoch Frith) is a situation which obviously is capable of being protected in all winds by a sufficient pier; and traces remained of imperfect efforts, which had no doubt been useful to small craft, although the large vessels of modern times had found destruction instead of shelter at this place. The shore is very flat, so that the pier extends three hundred and fifty feet in a direct line, ending with a return pier seventy feet long, and affords ample accommodation. This was effected by the contributions of Mr. Macleod of Geanies, Mr. Macleod of Cadboll, and of the Marquis of Stafford, who in this instance was willing to consider a place of shelter on the opposite side of the Dornoch Frith as within the scope of his Sutherland improvements. The moiety paid on the part of the public from the balances of the Forfeited Estates, exceeded £. 1,500, and the work was completed in September 1816.

Expenditure.		
£. 1,584	-	-
1,584	-	-
£. 3,168	-	-

Tobermory Pier.—At Tobermory, in the Isle of Mull, the British Fishery Society have an established station, which they were desirous of improving by a landing pier, not of much less dimensions, nor much less costly, than that at Portmaholmach. It extends three hundred feet into the bay, with a head or short return pier: the work was finished in November 1814, within twenty months from the date of the application to us for aid; the contractors, Messrs. Simpson and Wilson having in this, as in most other instances, gone beyond the stipulations of their contract, both in expedition and workmanship.

Expenditure.	
£. 1,555	-
1,555	-
£. 3,110	-

Banff Harbour.—Banff is a Port of considerable trade, situate on the west side of a small bay open to the north, as being on the coast of the Moray Frith. The harbour was very confined, and even before the present improvements commenced, might almost have been called artificial, being defended by a north quay and by an eastern pier placed on a projecting ridge of rocks; and within this containing a western pier and two jetties, useful as wharfs, as well as for stilling the agitation of the water. As long since as the year 1806, the inhabitants entertained a bold design of enlarging their harbour to the northward, where another inlet, with never less than a yard depth of water at the lowest ebbs, was in use as a boat harbour. After repeated investigations, and some variations in the details of this plan, it was pronounced to be expedient and practicable at an expense of £. 14,000. Of this sum we consented to defray a moiety, and the work was well advanced towards completion, when the same storm which overthrew the unfinished pier at Peterhead, as already stated,

Expenditure.		
£. 7,000	-	-
7,000	-	-
1,000	-	-
1,000	-	-
£. 16,000	-	-

committed no less ravage at Banff, with this unimportant distinction, that at Banff the stress of weather was on the 22d, at Peterhead on the 23d and 24th of October 1819, proving that the wind veered round more and more to the eastward during this hurricane; which at Portsoy destroyed one of the most ancient piers on the Moray coast.

The memorials of the sufferers at Banff and at Peterhead reached us at the same time, and, by a similar result, obtained the aid which had been destined for the improvement of other harbours, had not this emergency intervened.

The damage at Banff was estimated at £.2,000, and advantage has been taken of the experience gained by this misfortune to improve in some degree the new entrance of the enlarged harbour, which will become twice as spacious as before; that is, its area will be two acres; and the acre of Scotland is to that of England as five to four.

The outer end of the pier, founded on caissons, being advanced into water nine feet deep at the lowest ebbs, and twenty feet at high-water, affords a sheltered station, where the largest merchant vessel, when three-fourths laden in the harbour, may be placed inside the pier-head to complete her cargo; and of course may discharge one-fourth of an imported cargo at the same place.

Macduff.

THE PORT OF MACDUFF is situate opposite to Banff on the other side of the same bay, and was not much exposed to the great storm of 1819; in a former Report we stated an expectation that the Harbour of Macduff would also be improved under our superintendence; but circumstances delayed the expected contribution until all our disposable funds had been appropriated to other purposes: we understand however that improvement has lately been attempted, and in some degree accomplished.

Expenditure.

£. 1,904 - -
1,904 - -
£. 3,808 - -

DINGWALL CANAL.—The town of Dingwall (which has already been mentioned oftener than once in this Report) is situated on the great north road, at the head of the Cromarty Frith, which there receives the small river Peffer. Above the town this river used to spread itself into a small morass, which has been successfully drained; and a mile below the bridge and town coasting vessels used to be loaded and unloaded on the mud at low-water, their cargoes being carried on a bad road to and from the east end of the town. This inconvenience has been remedied by shaping the lower end of the river Peffer into a regular canal two thousand yards in length, with two wharfs, at which vessels of nine feet draft of water find complete accommodation. We learn with regret that the Dingwall canal is not so much attended to as the nature of the improvement demands; but we expect that when the necessity of the case becomes more manifest, the mud will not be suffered to accumulate, and that the turf and railing on the outer bank of the canal will be maintained in good condition.

At the date of our last Report, in the year 1817, Dingwall was the latest of harbour improvements which had been finally decided on. Those which have since been commenced (most of which have also been finished) we shall

arrange rather according to situation than date; and first proceed from Dingwall to other parts of the Cromarty Frith.

INVERGORDON FERRY.—Twelve miles from Dingwall, on the north side of the frith, is situate the populous village of Invergordon, opposite to which is Inverbreckie; and the ferry between these places is much frequented by the inhabitants of the Black-Isle, and by those who, having crossed the entrance of the Beauley frith at Fort George, are journeying to Tain or farther northward. Ferry piers of the best kind have lately been completed; that at Invergordon (including an addition of thirty yards to its length, at the earnest desire of Mr. Macleod, of Cadboll,) extending one hundred and thirty-three yards from high-water mark; that at Inverbreckie, ninety yards. These piers have been substantially built at an expense of £.1,638.

BALINTRAED PIER.—At Balintraed, three miles eastward from Invergordon, a landing pier of massive dimensions has been erected, for the express purpose of facilitating the importation of lime, coals, and other articles of consumption in the very fertile district of Easter-Ross, and for the exportation of corn and timber. The extent of this landing pier is one hundred yards, with a head or return pier, measuring forty feet (inside length), for improving the shelter from the southward. The expenditure will amount to about £.2,400; of which Mr. Kenneth Macleay contributes a moiety. The value of this improvement will not be duly appreciated, without considering that the Cromarty Frith is indeed one of the best and most extensive harbours in Great Britain, and that until the present time there was neither wharf nor pier along its northern shore, which may be deemed twenty miles in extent.

CHANNERY PIER.—The burgh of Fortrose, situate at the entrance of the Beauley frith, has already been mentioned; near to it a spit of shingle, called Channery Point, stretches almost a mile from the shore opposite to Fort George; and Mr. Mackenzie, of Flowerburn, the proprietor, has contributed half the expense of building a pier, which experience has proved to be requisite for the safety of passengers at this frequented ferry. This pier must be large and deeply founded in order to answer its purpose, and it is in a state of forwardness. The expense will be nearly £.1,300; and we have only to regret that the Ordnance Board have not felt themselves justified in constructing for the use of the garrison, and therein for the public service, an opposite ferry pier, at Ardersier, or Fort George, which has been estimated at the moderate expense of £.600.

NAIRN HARBOUR.—The county town of Nairnshire stands about half a mile from the sea, on a river also called the Nairn; and a new channel and outfall for this river has long been contemplated by the inhabitants as the best manner of obtaining a harbour, instead of the gravel beach, which offers no safe accommodation to the fishery or to commerce.

The wharf wall, one hundred yards in length, being flanked by two jetties projecting thirty feet, is placed advantageously on a rock, which was dis-

covered at a proper depth for the foundations, and forms a basin or recess on one side of the new river-channel, which has been cut from the bridge (east end of the town) to and across the great shingle strand, so that the entire improvement will probably be effected before the end of the present working season. The joint expenditure will amount to less than £.3,500; and this will have been judiciously applied, provided the river does not hereafter deviate from its new course, which a reasonable degree of attention may prevent.

Expenditure.
£. 2,070 - -
2,070 - -
£. 4,140 - -

CULLEN.—Forty miles eastward from Nairn, on the Moray coast, is the bay of Cullen, imperfectly protected towards the north; and Colonel Grant, who usually resides at Cullen House, proposed to contribute a moiety of the expense of building a solid pier two hundred and fifty feet long, with a head or return pier, chiefly for the accommodation of the fishery, and of removing certain rocks near the landing-place: finally a small check pier was placed at some distance to prevent the accretion of sand, which is swept round the bay, and might otherwise fill the spot chosen for the new harbour. The entire work, which cost above £.4,000, was completed at the close of the year 1819, and seems to answer the expectations of all parties concerned, as great activity prevails at the fishery station; and Colonel Grant is proceeding with other improvements, among which is a road of direct access to this new pier or harbour, which thus seems likely to give origin to a new Cullen.

Expenditure.
£. 995 - -
995 - -
£. 1,990 - -

GOURDON.—On the Kincardineshire coast, near Bervie, is an inlet called Gourdon, imperfectly sheltered by scattered and insulated rocks at a short distance from it, but not incapable of admitting the coasting trade, and containing many fishing boats, which find full employment. Mr. Farquhar, the proprietor, applied for aid towards constructing a pier, and clearing the entrance of the inlet; by which operations the place has been rendered commodious and secure at all seasons of the year, greatly to the benefit of an agricultural district, Gourdon having now become an intermediate shipping place between Stonehaven and Montrose, which are more than twenty miles apart. The joint expense of the work, to the harbour fund and the contributor, was £.2,000.

Expenditure.
£. 373 - -
373 - -
£. 746 - -

JURA, *Small Isles Pier*.—Under this title is designated a small pier adjacent to the Jura road, midway between the ferries of Lagg and Feoline. At this place the east side of Jura is indented by a bay, well sheltered by islets in the offing, and much frequented by herring busses and small coasters. The pier was built in the year 1814, Mr. Campbell, of Jura, contributing one-half of the moderate expense.

Expenditure.
£ 65 - -
65 - -
£. 130 - -

KIELLS FERRY PIER.—In common with the Kiells road, this ferry pier was improved in the year 1808; but was considered as requiring further improvement for the safety of the boat, and this was afforded from the harbour fund in the year 1818, the expense to both parties being £.130.

Expenditure.
£. 83 - -
£. 166 - -

ST. CATHERINE'S FERRY PIER.—Opposite to Inverary, on Loch Fine, a ferry pier, ninety yards in extent, has been built at St. Catherine's, equidistant from the northern terminations of the Strachur and Ardnoe roads, and is an example

of great convenience obtained at the moderate expense of £.166, one-half of which was paid by Captain Campbell, of St. Catherine's, the proprietor. Many such piers would be highly serviceable in the county of Argyll, indented and intersected as it is by the sea and by fresh-water lakes in all directions.

Kyle Rhea Ferry Piers.—These piers are clearly appendages of the western road to the Isle of Skye; but not having been included in any of the estimates or contracts, they were at last of necessity improved at the expense of the harbour fund, Lord Macdonald contributing one-half of £.1,146. The old piers were so much dilapidated, that little or no advantage was derived from them by the contractor.

Expenditure.
£. 573 - -
573 - -
£. 1,146 - -

Portree Landing Wharf.—The town of Portree, in the Isle of Skye, has been frequently mentioned in the Report of Roads as being the centre of communication in that island. To enable it to support this station with propriety and public advantage, Lord Macdonald offered to defray half the expense of a landing wharf in the harbour, and of a road of approach thereto; and these improvements were found, on final inspection in May 1820, to have been completely accomplished.

Expenditure.
£. 338 - -
338 - -
£. 676 - -

The result of the foregoing statement of the application of the available funds arising from the forfeited estates, is, that a sum of £.50,000 has been nearly doubled by the contributions of individuals, or from burgh funds. The objects have widely differed in magnitude, from £.30,000 expended at Peterhead, to less than £.200 elsewhere; but, on the whole, we are not aware that £.100,000 could have been more advantageously expended for the benefit of Scotland, in conformity with the expressed intentions of the Legislature as to the destination of the funds accruing from the Forfeited Estates.

We thus conclude our Report of Highland Roads and Bridges, on which has been expended the sum of £.450,000*:—of the Glasgow road, which, in amount of work done and contracted for, may be reckoned at £.50,000:—and of Harbours, in the improvement of which has been expended upwards of £.100,000; a large assemblage of improvements, produced on the same principle of local contribution, aided by public money; which we trust will in all future time be considered as having been judiciously as well as liberally given by Parliament for these truly national purposes; and that we shall be deemed to have administered effectually, and not improvidently, during eighteen years, the important charge committed to our care.

	£. s. d.
Highland Roads and Bridges -	450,000 - -
Glasgow - -	50,000 - -
Harbours, &c. &c.	100,000 - -
	£ 600,000 - -
Local Contributions - - -	550,000 - -
Total - £.	1,150,000 - -

April 1821. [Signed by the Commissioners.]

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* Between the years 1820 and 1828, was further expended about £.35,000 in completing the Roads and Bridges not quite finished at the date of the above Report—(*See the two next pages.*)

FINAL SUMMARY VIEW of the CASH TRANSACTIONS of the COMMISSIONERS FOR

Dr - - - - - - - - - (1.)—THE COMMISSIONERS - - - - - - IN

For Money received; viz.	£.	s.	d.
Parliamentary Grants - - - - - - - - - - - - - -	254,399	11	2
Interest on Exchequer Bills - - - - - - - - - - - - -	7,329	6	6
Ditto - on Money lodged in the Bank of Scotland - - - - -	1,411	14	6
Exchange on Remittances to Edinburgh - - - - - - - -	533	2	–
Interest received from sundry Contributors, on Balances due by them on settlement of Road Accounts - - - - - - - - - -	2,717	17	8
Received from the Barons of Exchequer in Edinburgh - - - - -	56	16	3
Received from the Cautioner of the Contractors for Auchnasheen Road -	506	11	6
£.	266,954	19	7

Dr - - - - - - - - - (2.)—THE COMMISSIONERS - - - - - - IN

For Money received; viz.	£.	s.	d.
From the sundry Contributors deposited in the Bank of Scotland - -	153,176	15	1
From the sundry Contributors in repayment of the Commissioners' Advances - - - - - - - - - - - - -	55,566	–	9
Interest on Deposits, at 4 per cent. - - - - - - - - -	9,910	14	1
£.	218,653	9	11

Dr - - - (3.)—THE COMMISSIONERS - - - STATEMENT OF GENERAL

To sundry Accounts for Monies received;	£.	s.	d.
Parliamentary Grants - - - - - - - - - - - - - -	254,399	11	2
Interest and Exchanges thereon - - - - - - - - - - -	11,992	–	8
From the Barons of Exchequer - - - - - - - - - - -	56	16	3
From the Cautioners for Auchnasheen Road - - - - - - - -	506	11	6
From sundry Contributors - - - - - - - - - - - -	208,742	15	10
Interest thereon - - - - - - - - - - - - - - -	9,910	14	1
£.	485,608	9	6

Memorandum:—It will be seen by comparing the above Accounts (No. 1. and No. 2.) that the public, in defraying the incurred; but the contributors being always bound to pay any extra expense beyond the estimated fession, will find in the distinctness of the two first Accounts, and their combination in the third Account,

HIGHLAND ROADS AND BRIDGES, from 20 October 1803 to 31 December 1827.

TRUST - - - - FOR PARLIAMENTARY GRANTS - - - - - - Cr.

		£. s. d.
By Expenditure; viz.		
On Surveys and Estimates, to be repaid by the Treasury - - -		5,207 14 10
On Charges of general management - - - - - - - -		46,627 – 5 ¼
On Roads and Bridges - - - - - - - - - -		213,534 18 5
Transferred to Road Repair Account, being a Balance due from Mr. Telford, on settlement of his Account -	£. 629 16 9 ¾	
Ditto - ditto - from Bankers in London - -	105 8 6	
		735 5 3 ¾
Transferred to Superannuation Bank of Scotland - - - -		300 – –
Paid to Harbours, Bank of Scotland, Balance due from that Account -		34 19 5
By Funds remaining		
In the Bank of Scotland, at 31 December 1827 - - - - - -		515 1 2
£.		266,954 19 7

TRUST - - - - FOR MONEY RAISED BY SUNDRY CONTRIBUTORS - - Cr.

	£. s. d.
By Expenditure; viz.	
On Roads and Bridges, in full of contribution thereto - - - -	201,786 14 11
Repaid the Contributors such part of the Contributions as appeared on a final settlement of certain Road and Bridge Accounts, to be above a moiety of the actual Expenditure thereon - - - - - -	16,866 15 –
£.	218,653 9 11

BALANCES ON 31st DECEMBER 1827 - - THE COMMISSIONERS - - - - Cr.

	£. s. d.
By sundry Accounts for Expenditure, &c.; viz.	
On Surveys and Estimates, to be repaid by the Treasury - - -	5,207 14 10
On Charges of general management - - - - - - - -	46,627 – 5 ¼
On Roads and Bridges from Parliamentary Grants - - - - -	213,534 18 5
Transferred to sundry Accounts from ditto - as above - - - -	1,070 4 8 ¾
On Roads and Bridges, from such Monies as have been actually deposited in the Bank of Scotland by the Contributors, or paid to the Commissioners by them - - - - - - - - - -	201,786 14 11
Repaid the Contributors for over Advances on the respective Roads and Bridges - - - - - - - - - - - - - - - -	16,866 15 –
By Balance provisionally paid over and remaining in the Road Repair Account, Bank of Scotland, but held applicable to rebuilding of Bridges and similar services, under the provisions of the Highland Road and Bridge Act - - - - - - - - - - -	515 1 2
£.	485,608 9 6

James Smith, Accountant,
29, Princes-street, Bank.

entire expense of management and superintendence, did in appearance pay in the proportion of five to four of the expense expense, the actual expense was not unequally borne.—The reader who may happen to be skilful in the accountant's pro- a model worthy of his attention.— *J. R.*

Appendix (L. 4.)

DESCRIPTION AND SPECIFICATION OF THE SPEY-SIDE ROAD.

ROAD from the Bridge over the River *Spey*, near *Grantown*, to and including the Bridge over the River *Avon*, at *Ballindalloch*.

1st Division.

From the south abutment of the bridge over the river Spey to the burn of Cromdale, being a distance of 2 miles 1,590 yards.

The south-east wing wall of Spey Bridge must be taken down and rebuilt, nearly parallel with the river; the rock for the foundations of this wall must be cut six feet in width, with its direction dipping into the bank, at a right angle with the outside batter of the wall. The thickness of the masonry to be six feet at an average, and carried to the proper height, to correspond with the parapet over the arch. The road must afterwards be carried eastward, with a very gentle rise along the face of the steep rocky bank, and have its lower side protected with a breastwork, and a parapet-wall upon the top of it, built with stone and lime, for 150 yards in length, and coped agreeably to the specification; and along the upper side a retaining wall will be required.

Proceeding forward, the line passes through the lower corner of a small inclosure, along the top of some arable land, crosses the head of a small valley, and then enters a more level moor, along which it proceeds in nearly a strait line to a small burn, which it crosses, and passes through a small cultivated inclosure, and along the low bank, partly through birch wood, and partly through a pasture-field, till it reaches the burn of Congash, where a twenty-feet arch will be required; the gravel for backing this bridge to be got from the corner of the east bank, in order to cut off the acute angle which the line makes immediately after crossing. From this point, the road keeps nearly the same level along the face of the bank, and below the garden of Congash, till it has passed the head of the small gulley, and then in a south-east direction, as marked on the ground, till it enters a birch-wood; it then crosses the burn, and then by the skirts of two projecting points; it then bends to the eastward, and follows the general direction of the old road, though partially deviating from it in several instances, to preserve the regularity of the surface. It then proceeds, nearly level, to about 170 yards beyond where the road branches off to Cromdale. At this point, instead of following the old road to the bridge of Milltown, which is ruinous, and inconveniently steep, it must descend along the face of the bank, in the direction marked off, till it reaches the bottom; it then keeps along the base, and nearly in the same direction to the burn of Cromdale, over which a thirty-five-feet arch must be built. The earth and gravel for forming the embankment at the west end of it must be taken from the east bank, in order to regulate the rise and uniformity of the road-surface at that place. Here the 1st Division ends.

Throughout the whole of this section, breast and retaining-walls will be required, with a very considerable quantity of cutting and embanking, in order to form the surface of

the roadway regular from one point to another. Where the new line will join the old road, about 300 yards lineal of earthern mound will be required between the road and the river. This mound is to be made on the solid ground, to be two feet and a half high, one foot broad at top, and to slope on the sides at the rate of three to one, and covered with green-swarded turf, laid flat. As most part of this division passes along the face and bottom of sloping ground, care must be taken to make a sufficient number of back-drains to collect the hill-water, and conduct it to the nearest bridge or covered drain. They are to be three feet wide at top, one foot at bottom, and of a depth sufficient to contain the water. As these dimensions are applicable for the drains on the other divisions, they need not be repeated.

Throughout this division, two arches of six feet, one ditto of twenty feet, and one ditto of thirty-five feet, per plan and specification, and twenty covered drains, two feet square each, will be required.

2d Division.

From the termination of the last section at Cromdale Burn to the Burn of Dalvey, measuring 3 miles 717 yards.

After leaving Cromdale Burn, the new line crosses the old road, passes along some flat ground, and cuts off some corners of arable land; it then gently descends along the face of a bank, and again enters some arable land, crosses the burn of Dalachaple, and passes through the garden, where it gains the face of a bank, and proceeds along it in the direction marked off by the head of some arable land, to the face of a steep hill, along which it is carried in the same direction, and on nearly a level, till it joins the old road at an acute bend in the river. It passes along the old road for a short distance, and then leaves it to the south-east, in order to avoid an inconvenient rise, and afterwards crosses it, just as the present road begins to descend into the flat moor of Dabieach. The intended line still keeps the face of the hill by the head of a patch of arable land, in the direction marked out, till it reaches a flat moor, over which it proceeds more than half a mile, when it again joins the present road, and runs parallel to it till it begins to descend a small bank. To avoid this, the new line is kept a little to the southward, and through the corner of an inclosure, and proceeds through some arable land, near the old road, till it begins to descend, near the burn of Dalvey. Here, instead of descending abruptly, the line must be carried over some small gulleys, and gently descend in the direction marked out on the ground, to the intended site of the thirty-feet arch on the burn of Dalvey, where the 2d Division ends.

Throughout the most part of this section, breast and retaining walls will be required, some of which will be of considerable height; between Dalachaple and the east moor of Dabieach, a vast quantity of deep and expensive side-cutting will be required, and perhaps some points of rock to remove; there will also be side-cutting in other parts of the Division, though of less magnitude. In this Division, 433 lineal yards of stone parapet will be required at different places, as will be pointed out by the road-inspector. It is to be built with lime-mortar, and coped, agreeable to the specification. Back-drains will be required, as described in the 1st Division. Six arches of three feet span one ditto of

four feet, one ditto of ten feet, and one of thirty feet, per plan and specification, and twenty-six cross-drains of two feet square each, will be required.

3d Division.

From the Burn of Dalvey to the east bank of the Burn of Advey, being a distance of 2 miles 1,085 yards.

The present old road, for some distance from Dalvey Burn, is occasionally overflowed by the waters of the Spey, to avoid which, the line, after leaving the bridge, must join the corner of the east bank, a little below the mill, pass along the inside of the stone dike, and fall into the old road at the point marked for that purpose, and proceed thereon for a short distance; but as the present road is too narrow, the stone dike along the upper side must be taken down from the commencement of the division to the lime-kiln, nearly opposite to the east end of the dike. This fence must be rebuilt in a substantial and workmanlike manner, to the height of four feet above the surface of the new road, and coped with a strong double turf. At Cairnglass there are some inconvenient bends on the old road, which must be taken off; from thence the line will be continued to Strenvel Burn, and, after crossing it, will proceed along a flat moor, with an easy curve, to a small gravelly bank, into which the road must be cut, in order to obtain materials for an embankment over a piece of marshy ground, which is sometimes flooded. This embankment must be raised to the average height of four feet, to be twenty-six feet wide at top, and to slope on the sides at the rate of two to one. From thence the line will begin to ascend along the face of the rocky and steep bank, and bending a little northward, till it reaches the top of it; it then crosses the old road, and passes by the bottom of the garden attached to the cottages, and bends easterly through a small arable field, and over some mossy ground. After ascending along the face of the hill, it re-crosses the old road, and with an easy curve proceeds over a flat moor, below the cairn of stones, to the upper side of the farm-house of Advey. The burn at this place, being in the bottom of a deep dingle, must be crossed by cutting the road out of the face of the bank, and descending gently to the site of the intended bridge, at a projecting point, where there is rock on both sides, the arch of which must be raised agreeable to the elevation, so as to correspond with the road. After crossing this burn, the Division ends.

Although this section is comparatively regular on the surface, yet, in forming the road, breast and retaining walls, with a considerable extent of cutting and embanking, will be required for nearly the whole distance.

In sundry places of this Division, a parapet-wall will be necessary, extending in all to 152 lineal yards, which must be built and coped as formerly described. There will be wanting one arch of three feet span, two ditto of eight feet, and one ditto of thirty feet span, per plan and specification, with fifteen covered drains of two feet square; also back-drains must be made for the whole length of the section, as described in the first Division.

4th Division.

From the Burn of Advey to the junction with the road already formed, and partly gravelled, about half a mile east of Tormore, measuring one mile eight hundred and seventy-eight yards.

From Advey Burn the line will pass along some moorish ground, through a copse of birch and an arable field, and along a flat moor to the ward of Advey, which will be nearly in a strait line, and in no place steeper than one in thirty; passing just above the two huts, the line bends round the base of the hill, with its steepest declivity one in forty-four, to some corn fields, and from thence falls, at one in one hundred and twenty, to a point about eighty yards above the farm-house of Tormore, where the burn of that name must be crossed by a sixteen feet arch; after crossing the burn, the line passes by an embankment, four feet six inches high and twenty-six feet wide at top, and from thence gently rises along the bank to a point about half way between it and the formed road, where it will pass through a hollow, and descend, at one in seventy-two, to the road before mentioned, where the Division ends.

Throughout this section, there will be some breast-work and retaining walls wanted, with cutting and embanking, though not to the extent required in the former Divisions. Two arches of three feet span, and one arch of sixteen feet, and nine covered drains of two feet square, will be required, with necessary back drains through the moorish and marshy ground, which must be made as before described.

5th Division.

From the end of the last section, to and including the gravelling of the bridge over the river Avin, at Ballindalloch, being one mile one thousand six hundred and one yards.

This Division proceeds wholly along the present road, which though in some instances it might have been better laid out at first, and the ascents and inclinations made more regular, yet, on the whole, the line is too good to be abandoned, and by a little attention in cutting off some of the irregular bends, and filling up the hollows before the new gravel is laid on, a safe and substantial road may be obtained. The road through this Division has been formed to the breadth of twenty-eight feet, and fourteen feet in the middle have been gravelled; but the gravel has neither been properly cleansed from sand and soil, nor separated from stones of an improper size. In order to make the surface of this Division equal with other parts of the road, the gravel must be wholly trenched over, and separated from the large stones, and other improper mixtures; after which, it must be gravelled to the breadth of eighteen feet, and to the depth of fourteen inches in the middle, and ten inches at the sides; but before laying on the additional gravel, the space between the present gravel and the bank on the upper side must be cut sufficiently wide and deep to receive it; and where the bottom is soft and mossy, it must be secured, agreeable to the annexed specification. A retaining wall must be built along the whole of the upper side, to prevent the earth, &c., from falling into the side drains. The cross drains now made must be examined and sufficiently repaired where necessary, and all the necessary back drains must be made anew.

In this section one bridge is built, but so inconveniently and awkwardly placed, that the wing-walls must be taken down and extended, to suit the road, and the parapets raised thirty inches above the surface of the roadway.

General Observations.

It must be observed, that throughout the whole of this line of road, the abutments of each of the bridges must be raised to such a height, as to prevent the water from lying

on the crown of the arches, or sinking through them, and at the same time the rise and fall over the arches shall not exceed one in twenty-four. The thickness of the wing-walls and abutments to be increased beyond the dimensions stated in the general table, according to the necessary height, and the whole of the bridges to be so laid out and built, that the parapets, when finished, may suit the roadway, without any irregular turning or bend.

It must also be observed, that the embankments forming approaches to all the bridges, shall be of the same breadth as that between the extremities of the bridge parapets, and from thence to run in a regular form and direction till they reach the formed road on the natural ground. The sides of the embankments are to be supported with stone bulwarks, agreeably to the general specification, or formed to the breadth of three feet on each side, beyond the general line of the road; the sides to slope at the rate of two to one, and that slope to be covered with turf laid flat.

The roadway must be laid out agreeably to the sod marks made on the ground, so that when finished, it may form regular inclinations from one to the other.

The roadway in all places, without exception, is to be formed to the full breadth of twenty feet, including the side drain and green margin on the lower side, and gravelled to the width of eighteen feet; but in all places where the road is formed on artificial ground, its sides must be supported by stone breastwork, built agreeably to the specification, and coped with a double turf, both thicknesses not to exceed six inches.

When the road is formed on sloping ground, and where stone cannot be conveniently had for building breastworks, the whole breadth of the road, side drains, and thickness of retaining walls, must be cut out of the solid ground, which will not be less than twenty-two feet.

The whole road and bridges are in every respect to be made agreeable to the ground report and general specification for Highland roads and bridges, and conformable to these general observations, and to the marks made on the ground.

GENERAL SPECIFICATION FOR HIGHLAND ROADS.

The said line of road shall, during its whole length, be formed to the full breadth of twenty feet in the clear, including the side drain and green margin, excepting in places where there is an absolute necessity for cutting the whole breadth of the road in solid rock; and in those places the breadth of the road shall be eighteen feet in the clear within the parapets, which may be necessary for a safeguard; and those parapets are to be two feet in thickness at the bottom, so that in rock the cutting will be twenty feet in breadth; and in all cases the road is to be so laid out, that there shall be no quick bendings, nor its upper side interrupted by points of rock. On dry-bottomed ground, gravel of a proper quality, out of which all stones above the size of a hen's egg shall have been previously taken, shall be laid to the depth of fourteen inches in the middle, and nine inches at the sides; but the stones which are taken out of the gravel, and do not exceed four inches in size, may be laid for that thickness below the gravel, and in that case ten inches only of cleansed gravel will be required. On mossy ground or swampy soils, if the moss or soft matter is not more than two feet in thickness, and a hard bottom below this moss or

soft matter, it is to be wholly removed, and the road formed on the harder substance, as above described; but when the moss or soft matter is more than two feet in depth, the contractors are to have their option of either removing it, or forming the road upon the top of it, in the following manner:—Where the surface is level, and covered with sound sward or heath, the gravel may be laid upon the top of it; but where there is no sward or heath, there must be laid two rows of swarded turf, with the swarded side of the one downwards, and of the other, which is to receive the gravel, upwards; or otherwise, where turf cannot be readily procured, the surface of the moss or soft matter may be covered with a layer of brushwood or heath, which, when compressed, shall not be less than six inches in thickness; upon the surface, so compressed and prepared, there shall be laid gravel, cleansed as before described, to the thickness of eighteen inches in the middle, and thirteen inches at the sides. In all cases, whatever be the nature of the soil, the road is, on all flat ground, to be brought to a perfect level from side to side before the gravel is laid on; but in all cases where the road is to be raised on the one side by moved ground, while the upper side is on natural ground, the lower side of the road, when finished, is to be from four to six inches higher than the upper side, in proportion to the quantity of moved ground on the lower side. In side-cuttings, in steep banks, even if there is no moved ground on the lower side, still the lower surface of the finished road is to be on at least four inches higher level than the upper side. Where the ground is level or flat, the road is to be gravelled to eighteen feet in width, and to have a border of green turf on each side one foot in width. When the road is formed on a sloping bank, where no parapets are necessary, there is to be a border of green turf on the lower side of the road, one foot in breadth, in the clear. These drains are to be formed perfectly regular, and so as the course of the water shall not be interrupted by points of rock or sudden turnings; and where the soil is soft and loose, these drains, on the upper side of the road, are to be paved with small stones, not less than four inches in depth; these pavements are to be made at the places pointed out by the inspector; they are to be carried to the extent and made in the shape as he shall direct. Where the parapets are necessary, the road is to be gravelled to the breadth of eighteen feet, as before described. And also the said contractors bind and oblige themselves, and their foresaids, to make in a sufficient manner all back-drains of such dimensions and in such directions as shall be necessary for effectually collecting and conducting the water in a proper manner from the higher grounds to the nearest bridges or covered drains, especially where the road is formed along steep and sloping banks, and the ground is wet and swampy, and that at the places which shall be pointed out by the said surveyor, so that the road shall always be kept free of water. Where the road is to be formed upon level ground, and particularly where it is mossy and swampy, side-drains are to be made of a sufficient depth to drain the ground, and in all cases quite sufficient to convey the water. These side-drains to be made with a slope from the road to within one foot of the farther side of the drain, so that if the depth at the farther side be thirty inches, the width at the top shall be six feet, and so more or less, in proportion to the depth; and which side-drains shall be made at the places approved of by the surveyor; and also to make covered drains of dry stones at all places where necessary; the inside walls of these drains are not to be less than two

feet in thickness, and the stones for that width to be laid regular. These covered drains shall in no instance (without particular directions in writing from the principal engineer employed by the commissioners) be less than two feet square; they are to be properly secured in the bottom, by paving with stones set on edge; the pavement, as well as the sides, are to be secured at both ends of the drains by stone-work; so that it shall appear evident there is no risk that they shall be injured by the water, where it enters into or issues from the drain. The stones with which the two-feet drains are covered, are to be not less than three feet in length, and four inches in thickness, and laid so close together, or stones of equal length overlapping each joint, as shall effectually prevent the gravel from passing down into the drain, and leaving a hole in the road. But, in case it shall be discovered, during the execution of the road, that, instead of some of the two feet, the road may be better protected by making a greater number of drains of smaller dimensions, the contractors, upon receiving instructions in writing from the principal engineer, shall execute them in such manner, and counting two drains of eighteen inches, or three drains of twelve inches, in lieu of one drain of two feet square; and, in case of drains of eighteen inches being made, the stones of the covers shall not be less than thirty inches in length; if of twelve inches, the covers to be two feet in length; and, in order to secure the due execution of the said covered drains, it is expressly declared, that the same shall be subjected to the inspection and approval of the resident surveyor before the covers are laid on, that he may be satisfied that the bottoms are properly paved, and the sides are built in a sufficient manner; and after the said drains are covered, the backs of the buildings are to be made up with stones to the level with the upper bed of the covers; and the said drains shall be constructed so that they shall have a sufficient covering of gravel, not exceeding twelve inches, to the satisfaction of the surveyor, without causing any swell on the road. And also the said contractors bind and oblige themselves and their foresaids to build and erect breastworks of stones at all places where necessary, on the lower side of the road, along the side of watercourses, or on sloping banks, or on rocks; the foundation of the said breastwork must be cut into the rock or solid ground for the whole breadth of the base of the wall or breastwork, which is to be placed on it, as hereafter described, and its direction is to be dipping into the hill, at a right angle with the slope of the face of the breastwork. If it shall be necessary to make the breastwork three feet in height from the foundation to the level of the lower side of the road, the breadth of the foundation shall be twenty-four inches, and eighteen inches at the top or level of the lower side of the road. If the height is four feet, the breadth at the foundation is to be thirty inches, and at the top twenty-four inches. If the height is six feet, the breadth at the foundation is to be three feet, and two feet at the top. If the height is eight feet, the breadth at the foundation is to be four feet, and at the top two feet; and so on in proportion to any greater or lesser height. In forming these breastworks, the stones are to be laid in a regular manner quite through the thickness here described; the slope which is necessary to bring the wall to its thickness at the top is all to be taken off the outside, and the stones are to be laid mostly lengthways into the wall; the space behind the breastwork and natural ground, up to the level of the top of the formed roadway, is to be filled up with coarse gravel or stones (neither sand, soil, sods nor moss to be

used), and if with stones, they are to be covered and brought to the levels formerly described, with a layer of strong swarded turf, before the cleansed gravel is laid on.

At all times, when the nature of the cutting makes it possible, the resident overseer shall have an opportunity of examining the breastworks, when completed, before the inner side shall be filled up with stones or gravel as aforesaid; and also, where it shall be necessary for the due execution of the said road to erect parapet walls above breastworks, or upon rock, they are to be built with stones laid in good lime mortar, agreeably to the ground report. These parapets are to be two feet wide at the foundation, and eighteen inches at the top. The height above the finished roadway is to be two feet nine inches, including a coping of stones nine inches in depth; these coping stones are to be chosen so as to meet one another, in close regular beds or upright joints, to be firmly wedged together, and pointed with lime mortar. At each extremity of the parapets the copings are to be well secured, with the ends turned down under the roadway; and also, where it shall be necessary, in forming the road, to cut and remove earth from the higher side to the depth of two feet or more, the road must be formed twenty-one feet six inches wide, and, to prevent the earth from falling into the drain on the upper side of the road, a wall of dry stones, erected of a height according to the depth of the cut. The foundation of these retaining walls is to be laid in all cases six inches below the bottom of the drain, on the upper side of the road; there the thickness is to be from fifteen to eighteen inches, to the height of four feet; above that height, they are to be one-third of the height. The stones with which they are constructed are to be laid in a regular and workmanlike manner for the whole of the thickness of the wall; they are to be carried to such a height that the slope from them to the solid ground of the bank above is not to be less than two horizontal to one perpendicular, and that slope to be covered with turf laid flat. And further, the contractors are to be bound to cut down all heights, fill up all hollows, and blow all rocks upon the said line of road, as pointed out by the said Reports, and which shall be requisite and necessary for the same; and further, the said line of road shall be formed and prepared for the gravel for one mile at least per advance, to the satisfaction of the surveyor employed by the said commissioners, before any of the cleansed gravel is laid on.

PARTICULAR SPECIFICATIONS FOR THE BRIDGES.

1st. Cromdale Bridge.

This bridge is to be built at the place now marked off for it, and is to consist of one arch of thirty-five feet span, the rise of which is to be eleven feet eight inches. The foundations of the abutments are to be laid at three feet under the bed of the water at that place; they are to be five feet six inches in thickness, in the narrowest part, and the arch is to spring at three feet above the common bed of the water. The arch-stones to be two feet four inches in depth, to be closely jointed, and laid in regular courses quite through the body of the arch, and each course to be brought to a perfect level between the outside headers.

The foundations of the wing-walls to be laid as low as the bed of the water; they are to be twenty-five feet in length from the face of the abutments, and to be five feet in thickness at the foundations, and to diminish by regular off-sets taken from the inside to

two feet, at one foot under the surface of the finished roadway, and these off-sets to be divided into three equal heights. Solid masonry is to be built over the abutments for five feet in height above the springing to the arch.

The roadway between the parapets is to be eighteen feet in the narrowest part, and the rise and fall over the arch is not to exceed one in twenty-four in the steepest place. The parapets are to extend the whole length of the bridge and wing-walls, to be three feet in height above the finished roadway, and eighteen inches in thickness, coped with stones set on edge with close upright joints, not less than nine inches deep, and have their ends curved down to the roadway. The whole of the masonry of this bridge is to batter and curve agreeable to the general specification for bridges.

The embankments at both ends of the bridge, especially at the west end, must be carried from the crown of the arch with a gradual declivity, till it reaches the highest part of the arable field on the west side of the burn; it is to be supported by a stone breast-work for twenty feet from the end of the wings, and, as stones are not convenient, the remaining length may be sloped on the sides at the rate of two horizontal to one perpendicular, when the top is kept at the width specified in the Report. The embankment formed in the same manner on the east side to be carried into the natural ground, which is no extra distance. The space between the wing-walls and spandrils to be filled up with dry stones or coarse gravel, and the roadway over the arch and embankments must have a covering of cleansed gravel eighteen inches in depth.

Between the abutments of the bridge, and for five yards above and below, an inverted arch must be made with stones set on edge; these stones must be not less than eighteen inches in depth, and firmly wedged together.

The banks of the burn above and below the bridge must be cut strait for one hundred and twenty yards each way, and for that distance the channel for the water is to be as wide as between the abutments. The banks on each side are to be secured by stone bulwarks for the above distance; the foundations of these buildings must be laid one foot under the bed of the burn, and carried to the height of four feet above it; to be two feet thick at bottom, and eighteen inches at top. Where the natural ground is not of that height, the bulwarks are to be backed with earth and gravel, sloping outward, at the rate of three to one, and covered with green turf laid flat. The whole of this bridge to be built with proper stones laid in good lime mortar, and in all respects agreeable to the plan and elevation.

2d. Dalvey Bridge.

This bridge is to be built at the place marked off for it, and is to consist of one arch of thirty feet span; the rise of which is to be ten feet, and in all other respects to be of the same form and dimensions as described for Cromdale bridge.

3d. Advey Bridge.

This bridge is to be built across the Burn of Advey at the precise place marked off for it; it is to consist of one arch of thirty feet span, the rise of which is to be fifteen feet. The foundation of the south-east abutment is to be laid on the solid rock, near the bed of the burn; the rock for that purpose is to be cut and levelled for twenty-six feet in length, and

six feet in breadth, and to be brought to a perfect level for the whole of that space. At that depth the masonry is to be begun, and carried to the height of twenty-one feet from the bed of the burn, and to the full width of six feet in the thinnest part. On the west side the projecting rock is to be levelled, and the arch is to spring off it at the same height with the south side. The depth of the arch-stones to be two feet, and laid in regular courses, with close joints through the arch, and each course to be brought to a level between the headers.

The wing-walls are to be twenty-five feet in length from the face of the abutments; their foundations are to be cut into the solid rock, by square steps, as shown in the elevation; they are to be four feet in thickness at the foundations, and two feet at one foot under the surface of the finished roadway. Solid masonry is to be built over the abutments for six feet in height above the springing, and then sloped up as a backing to the arch, as represented by the dotted line.

The roadway between the parapets to be eighteen feet in the narrowest part. The parapets are to extend the whole length of the arch, and wing-walls to be three feet in height above the finished roadway, and eighteen inches in thickness, and coped with hammer-dressed stones set on edge, with close upright joints, not less than nine inches in depth, with their ends curved down to the roadway. The whole of the masonry of this bridge is to batter and curve, agreeably to the general specification for bridges. The space between the wing-walls and spandrils to be filled up with dry stones or coarse gravel; but the roadway over the arch and embankments to be covered with cleansed gravel, laid eighteen inches in depth.

At the ends of this bridge, breastworks and embankments are to be made to form the road; they are to extend from the ends of the wing-walls till they reach the natural ground. From the south-west wing-wall a parapet is to be built on the lower side, till it reaches the arable land at the corner of the garden, which is about eighty-five yards in length; and on the opposite side about ten yards of parapet is required. On the north-east side of the gulley about twenty yards of parapet will also be required, in addition to the length of the wing-wall; these are all to be built and coped the same as the bridge parapets.

The whole of this bridge to be built with proper stones, laid in lime mortar, and in every respect according to the plan and elevation.

GENERAL SPECIFICATION FOR BRIDGES.

Bridges of stone and lime mortar to be built over each river and stream, as pointed in the report and plan.

The foundations, in every case where it is practicable at a reasonable expense, to be sunk to and laid on rock.

Where rocks cannot be got at, the foundations to be sunk, at least, two feet below the lowest part of the bed of the river at that part. If the ground is soft, or the gravel loose, there must be a platform of timber laid under the foundations of the masonry. This platform of timber laid under the foundations must consist of two thicknesses of three-inch plank laid crossing each other, and, if necessary, have a row of pile-planking driven all

round the outside. If the ground is hard, instead of a platform under the foundations, there must be an inverted arch or pavement laid and wedged between the abutments, to be fully the width of the bridge, and well secured above and below by means of rows of stones sunk deeply into the bed of the river or stream. The span of each arch to be according to the annexed statements. The breadth of the roadway between the parapets to be eighteen feet in the narrowest part. The parapets to be not less than eighteen inches in thickness, of the height mentioned in the annexed Table, coped with hammer-dressed stones, set on edge in lime-mortar, not less than nine inches in depth, with a large stone at each extremity of the parapets. Where the ground requires it, there are to be retaining walls of dry stone of sufficient thickness, as described for breastworks, to support the made-up ground, and these walls are to run from the extremity of the parapets into firm ground, except the distance shall exceed twenty yards. When the bridges are not set upon rock there must be bulwarks of dry stone above and below the abutments, of ten yards in length from the abutments. The dimensions of the masonry to be agreeable to the annexed Table. The spandrils of the arches to be filled with stone or coarse gravel, so as the rise and fall of the roadway over the bridge shall not exceed one in twenty-four in the steepest places. The roadway to be formed of properly cleansed gravel to cover the top of the arch at least fourteen inches. Each bridge of one arch to be built so that the parapets, when finished, shall each have a curve, horizontally, of not less than three feet in thirty-six feet in length, and all the bridges to batter vertically at least one foot in twelve of height, and in this height also to have a concave curve of four inches.

TABLE.

Span of Arch.		Rise of the Arch from the Springing.		Depth of Arch-stones.		Height of Abutments from Bed of the River to Springing.		Thickness of Abutment Walls, on an average.		Length of Parapets from the Face of Abutments, with Wings under.		Height of Parapets above the Crown of the Arch-stones.		Thickness of Spandrils and Wings, on an average.		Thickness of the inverted Arch, where necessary.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
4	–	1	6	1	–	2	6	1	6	9	–	1	2	1	6	–	9
6	–	2	–	1	–	2	6	2	–	10	–	2	2	1	6	1	–
8	–	3	–	1	2	2	6	2	–	12	–	3	2	2	–	1	–
10	–	3	6	1	3	3	–	2	6	12	–	3	2	2	–	1	–
12	–	4	–	1	4	3	–	3	–	14	–	3	2	2	6	1	–
18	–	6	–	1	6	3	–	4	6	18	–	3	2	2	9	1	4
24	–	8	–	1	9	4	–	5	–	24	–	4	2	2	9	1	4
30	–	12	–	2	–	4	–	5	6	30	–	4	2	3	–	1	6
50	–	15	–	2	6	6	–	6	6	36	–	4	8	3	6	1	6

Note.—Spandrils between arches and at abutments are to be filled between the outside walls with solid masonry above the level of the springing of the arches up to one-third of the height of the rise of the arches.

These dimensions are averages varied according to particular circumstances.

ANALYSIS of Expenditure on the Repair of Highland Roads and Bridges, during Ten Years, 1814-1823; shewing the Expenditure in each County, the Portion thereof repaid or due by the Heritors, and the Expense of Management.

IN THE YEARS		Expenditure on the Roads and Bridges. £.	s.	d.	Expense of Management. £.	s.	d.	TOTAL Expenditure. £.	s.	d.
1814 - - -	In Ten specified Counties.	2,253	9	8	135	15	11	2,389	5	7
1815 - - -		3,075	10	5	628	15	10	3,704	6	3
1816 - - -		4,308	9	10	786	17	6	5,095	7	4
1817 - - -		4,254	6	9	939	7	2	5,193	13	11
1818 - - -		5,470	3	3	943	5	9	6,413	9	-
1819 - - -		7,564	11	8	1,189	9	1	8,754	-	9
1820 - - -		9,034	10	4	1,418	15	8	10,453	6	-
1821 - - -		6,356	3	10	1,583	5	9	7,939	9	7
1822 - - -		5,851	2	4	2,136	5	10	7,987	8	2
1823 - - -		6,944	17	5	2,665	1	7	9,609	19	-
Totals -	- - -	55,113	5	6	12,427	-	1	67,540	5	7

If £.55,113 : £.12,427 : : £.100 : : : £.22. 10. 7. Therefore say 22½ per cent. for management.

RESULTS of the operation of the Highland Road Repair Act of 1814 (54 Geo. III. c. 54), and of the above calculations of the comparative expenditure of the two parties, adding to the portion above stated, as repaid or due by the Heritors of the several Counties, Five per Cent. for 15 Months' Interest on the Advances made for Road Repair on the part of the Public, which Advances are habitually made in the course of one year, and not usually repaid (nor probably levied on the Heritors) until near the end of the succeeding year, thus constituting an advance of 15 Months on an average; nor can the interest of money be rated lower than four per cent. per annum during the period of this account, so that the benefit bestowed on the Counties by advance of money on their behalf cannot be computed at less than five per cent. on all such money advanced.

	£.	£.
Inverness*		
Expenditure as above stated - - - -	30,977	
Add five per cent. as interest on £.13,780, appearing to have been advanced for the repair of roads - - - - - -	689	31,666
Whereof the Heritors have paid - - - - -		13,780
The Public have paid - -	£.17,197+689=	17,886
Ross (with Cromarty :)		
Expenditure as above - - -	8,305+180=	8,485
Whereof the Heritors have paid - - - - -		3,600
The Public have paid - - -	4,705+180=	4,885
Sutherland :		
Expenditure as above - - -	4,435+109=	4,544
Whereof the Heritors have paid - - - - -		2,196
The Public have paid - - -	2,239+109=	2,348
Caithness :		
Expenditure as above - - -	2,172+ 57=	2,229
Whereof the Heritors have paid - - - -		1,157
The Public have paid - - -	1,015+ 57=	1,072
Argyle :		
Expenditure as above - -	16,004+476=	16,480
Whereof the Heritors have paid - - - - -		9,536
The Public have paid - - -	6,468+476=	6,944
Elgin or Moray :		
Expenditure as above - - - -	3,083+85=	3,168
Whereof the Heritors have paid - - - - -		1,702
The Public have paid - - -	1,381+85=	1,466
Aberdeen :		
Expenditure as above - - - -	917+27=	944
Whereof the Heritors have paid - - - - -		558
The Public have paid - - -	359+27=	386
Bute :		
Expenditure as above - - - -	847+24=	871
Whereof the Heritors have paid - - - - -		492
The Public have paid - - -	355+24=	379
Nairn :		
Expenditure as above - - - -	511+15=	526
Whereof the Heritors have paid - - - - -		311
The Public have paid - - -	200+15=	215
Banff :		
Expenditure as above - - - -	291+ 8=	299
Whereof the Heritors have paid - - - - -		173
The Public have paid - - -	118+ 8=	126

Observations upon the Results.

1.—The portions of the total expenditure paid by the heritors and by the public during the above period of ten years, differ not very materially in amount; the heritors (in the aggregate) having paid (or being now in debt to the Commissioners) about £. 33,505, the public having paid £. 34,035, or, including interest on advances, £. 35,710; but the effect of the limitation of assessment (59° G. III. c. 135.) has been such, that towards repairing the roads and bridges in the county of Inverness, the public have paid £. 4,106 more than the heritors, while in the county of Argyle the heritors have paid £. 2,592 more than the public.

2.—The expenditure on road repair, paid by the heritors of the several counties, has been in the following proportions:—By the heritors of the county of Inverness 44 per cent. on the total expenditure in that county; in Ross-shire 43 per cent.; in Sutherland 47 per cent.; in Caithness 53 per cent.; in Elgin 55 per cent.; in Argyle 60 per cent.; in Bute 58 per cent.; in the counties of Aberdeen, Nairn and Banff (which have not profited at all by the limitation of assessment) 61 per cent. The county of Ross has profited in greater proportion than even the county of Inverness, two roads having been repaired in it at considerable expense, although not military roads, nor made under the care of the Commissioners. [These roads are described in the Road Repair Act, 59 Geo. III. c. 135, s. 4.]

3.—The limitation of assessment (without including interest on the annual advance of one year's expenditure) has cost the public upwards of £. 7,800, and hereby profited the heritors of the county of Inverness £. 5,180; the heritors of Ross-shire, £. 1,473; of Sutherland, £ 518; of Caithness, £. 172; of Argyle, £ 248; of Elgin or Moray, £. 190; of Bute, *i. e.* Arran, £. 26; such being the amount of benefit bestowed on these counties respectively, beyond what was originally intended by the Legislature:—the heritors of the counties of Aberdeen, Nairn and Banff, have not profited at all by the limitation of assessment, their payments being comparatively of trifling amount.

4.—For the sake of brevity and compression, the fractional parts of a pound sterling are not expressed in the above statements of the annual expenditure of repairing the roads and bridges of the several counties; but are taken into account in the *additions*, and consequently in all the *calculations, results* and *observations* founded thereupon. *J. R.*—1824.

APPENDIX (L. 5.)

MILITARY ROADS in the HIGHLANDS repaired by the PARLIAMENTARY COMMISSIONERS.

MILITARY ROADS, and ROSS-SHIRE ROADS near *Dingwall*, repairable under the Act of 1819.

ROADS.	County of Inverness.	County of Argyle.	County of Moray or Elgin.	County of Ross.
	Miles.	Miles.	Miles.	Miles.
Badenoch Road - - - - -	52	—	—	—
Boleskine Road - - - - -	33	—	—	—
Conan Bridge Roads - - - -	- -	- -	- - -	8
Corriarick Road - - - - -	30	—	—	—
Dalmally Road - - - - -	- -	27	—	—
Duthel Road - - - - - -	- -	- -	6	—
Fort George Road - - - - -	16	—	—	—
Fort William Road - - - - -	45	—	—	—
Glencoe Road - - - - - -	- -	31	—	—
Glencroe Road - - - - -	- -	22	—	—
Grantown North Road - - - -	- -	- -	9	—
Grantown South Road - - - -	- -	- -	12	—
Invergordon Road - - - - -	- -	- -	- - -	17
TOTALS - - -	176	80	27	25

SUMMARY OF THE EXTENT OF ROAD-REPAIR IN EACH COUNTY.

IN THE COUNTIES OF	Parliamentary Roads.		Military Roads.	Dingwall Roads.	Total Roads Repairable.	
	Miles.	Yards.	Miles.	Miles.	Miles.	Yards.
INVERNESS - - - -	346	467	176	- -	522	467
ARGYLE - - - - -	134	132	80	- -	214	132
ROSS and CROMARTY -	186	1,384	- -	25	211	1,384
SUTHERLAND - - - -	95	634	- -	- -	95	634
CAITHNESS - - - -	54	1,365	- -	- -	54	1,365
ELGIN or MORAY - -	7	903	27	- -	34	903
BUTE - - - - -	16	1,247	- -	- -	16	1,247
ABERDEEN - - - -	16	200	- -	- -	16	200
NAIRN - - - - -	13	1,627	- -	- -	13	1,627
BANFF - - - - -	3	602	- -	- -	3	602
TOTALS - -	874	1,521	283	25	1,182	1,521

TABLE, showing the Proportion and Distribution of Expense paid by the Commissioners, and the several Highland Counties, assuming the usual Expense to be (as in the year 1823) about £.9,500 per annum; towards which the Annual Allowance on the part of the Public is £. 5,000.

COUNTIES.	Miles of Road.	Allowance by the Commissioners.	Additional for Annual Repair of Bridges.	Allowance to each County.	Estimated Expense of Inspection and Management.	Total Expense incurred by the Commissioners.	Payment which will be thereupon due from the County Assessments.			Total Expenditure on Road and Bridge Repair, *not including Management.*			Rate per Mile for Road Repair.	
		£.	£.	£.	£.	£.	£.	s.	d.	£.	s.	d.	£.	s.
Inverness - -	523	1,046	+ 20	= 1,066	+ 1,066	= 2,132	1,516	14	4	2,582	14	4	4	18
Ross and Cromarty	212	424	+ 14	= 438	+ 438	= 876	758	5	-	1,196	5	-	5	9
Sutherland - -	96	192	+ 30	= 222	+ 222	= 444	309	15	7	531	15	7	4	15
Caithness - -	55	110	+ 5	= 115	+ 115	= 230	204	-	-	319	-	-	5	11
Argyle - -	215	430	+ 15	= 445	+ 445	= 890	1,019	2	10	1,464	2	10	6	11
Elgin or Moray -	35	70	+ 14	= 84	+ 84	= 168	252	-	-	336	-	-	8	-
Aberdeen - -	17	34	+ 15	= 49	+ 49	= 98	147	-	-	196	-	-	8	-
Bute - - -	17	34	+ -	= 34	+ 34	= 68	102	-	-	136	-	-	8	-
Nairn - -	14	28	+ 5	= 33	+ 33	= 66	99	-	-	132	-	-	8	-
Banff - -	4	8	+ 6	= 14	+ 14	= 28	42	-	-	56	-	-	8	-
Totals -	1,188	2,376	+ 124	= 2,500	+ 2,500	= 5,000	4,449	17	9	6,949	17	9	—	

Appendix (L. 6.)

AGREEMENT for the Repair of Highland Roads, made under the Authority of the Parliamentary Commissioners.

In consequence of my communings with C. D., Road Inspector, I, A. B., do hereby agree to keep in repair the ———— road, commencing at ———— and terminating at ———— measuring ———— miles, from this date to the ———— for the sum of £. ———— or at the rate of £. —— per mile.

It is understood that I am to be responsible for the whole surface of the road being at all times kept and left in good repair; also for keeping it free from stones, timber, earth, rubbish, or any other matter which may obstruct the watercourses or travelling on the road; and that the proper shape of the road shall be preserved, and the gravelling or metalling be kept in proper order; and that all new gravel or metal required to fill up the wheel-tracks, and all other irregularities in the surface, shall be previously selected in the pits of a durable quality, and separated from all stones above the size of four ounces weight, also separated from all improper mixtures, to the satisfaction of the inspector.

I also agree, that the quantity of metal or gravel now on the road shall not be less at the expiry of my agreement, and that I am also responsible for keeping at all times, and leaving in good repair the whole cross, side and back drains; and all rubbish removed from thence shall be thrown over the lower side of the road; also to keep and leave in

good repair all the parapets, breast-works and retaining walls; and that all breaches in these buildings shall be repaired at my expense, unless the same shall extend to twenty cubic yards at one place, in which event the expense of repairing them shall not fall under this agreement.

I shall be answerable for the proper pointing and pinning of all the bridges and parapets on the said road, and for keeping in repair the inverts and water-walls, and the water-courses clear of rubbish, but for no accident which may befall the bridges.

And I engage the whole of the work specified shall at all times be kept and left in good repair, to the entire satisfaction of the inspector, ———————— who is to be sole judge of the extent of work which may fall under this agreement.

I am to receive ———————— of the said price, at the end of ———————— next, ———————— in the month of ———————— (provided the whole roads, bridges, parapets and watercourses at these terms are found in a complete state of repair), and the remainder at the expiration of my engagement, when the whole shall be approved of by the inspector.

And as this missive has been countersigned by C. B., I hold the agreement completed.

(signed) *A*—— *B*——
C—— *D*——

Appendix (L. 7.)

AGREEMENT for the Repair of a Military Road.
(The Badenoch Road.)

This line commences at the south end of the Moy road, and proceeds by Car bridge, and through the valley of Strathspey and Badenoch to the boundary of Perthshire, near the summit of the hill of Druemochter, and measures in all about fifty-two miles.

The repairs lately performed on this line have improved it very considerably, and it must have since given very general satisfaction; but, as the traffic is extensive and yearly increasing, the surface requires an annual supply of fresh materials to preserve its form, and make up such breaches as may happen during winter.

In order more particularly to point out the repairs required this season, and the manner of performing them, the line is divided into sections, as usual.

Section I.

From the end of Moy road to Car bridge, being a distance of about ten miles, the road was originally made either with soft materials or on a mossy bottom, which is always liable to decay. From the commencement to Freeburn Inn the surface is hollow, and requires a close covering of gravel all the way, and the breaches in the sides which have been made by cattle must be repaired, by laying a turf border of two thicknesses along it, with a sufficient quantity of gravel to make up the hollows. From thence to Findhorn

bridge the road in general is good, but some wheel-tracks and hollows must be made up with gravel. About the middle of this distance, the road during wet weather is muddy, and requires a covering of sharp gravel, laid to the average depth of two inches for four hundred yards, and the materials carted from the pit north of the eight-feet arch.

In this distance, one bridge of eight feet, one of twenty feet, and one of three arches, across the river Findhorn, must be pointed and the parapets repaired.

From the last-mentioned bridge to the county road in the Birchwood, the road is in a tolerably good state, excepting some trifling wheel-tracks, which require patches of gravel; from thence to Mrs. M'Queen's house the surface is generally too flat, and requires a close covering of gravel, laid to the depth of two inches, on the middle of the road, diminishing to the sides; this gravel must be of the best quality, and carted from a distance, there being none of good quality in the neighbourhood. From the sand-house, proceeding southward for five hundred yards, the road is also flat, and part of the small gravel washed off by the winter rains, and now requires four inches of gravel or rotten rock, carted from the best pit at the north end of the lot; and in doing this, care must be taken to select the largest of the stones, and reduce them to the size of four ounces weight, and lay them regularly on the whole tracks and hollows; after which, a stratum of good gravel is to be laid to the specified thickness.

From thence proceeding forward for fifteen hundred yards more, the road having been made of soft materials, is every winter cut from six to ten inches deep; this must be prevented in future by gravelling it nearly in a similar manner; that is to say, the stones on the road-sides and in the gravel-pits are to be collected and broken as above described, and laid for the whole breadth of the road; after which, an additional quantity of rotten rock is to be carted from the pit, at the junction of the old road to Corryburgh, or from any other of equal quality, and laid over the stones, so that both thicknesses shall not be less than eight inches in the middle of the road, and four inches at the sides, and in some places a turf border will be required. Where the road surface is lower than the adjoining ground, off-lets are to be made at the distance of thirty or forty yards, to carry off the surface-water.

From thence to two hundred yards south of the narrow pass at Slackmuicht, being about a mile, the road in general is too flat, and, as the declivities are steep, the water carries a part of the small gravel along with it. Gravel must now be carted from the pit at the north end of the narrow pass, and laid three inches deep on the middle, and one at the sides. The parapets on the road-side to the extent of one hundred and forty yards must be repaired, by taking out all the loose stones, and replacing them in lime mortar; after which, the whole is to be neatly pointed with proper mortar, and at the south end of the said parapet a cross drain of twelve inches is required.

From the above-mentioned point to the summit, south of M'Donald's house, the road in general is in tolerably good order; but along all the steep braes a close covering of gravel must be laid, to prevent the water running down the middle of the road. From the said summit southward, for six hundred yards, the road is soft, and requires four inches of gravel carted from the pit at the north end; from the north end of the flat moss to the

first bridge, being about one mile and a half, the surface is in pretty good form, but requires a close covering of gravel all the way to fill the wheel-tracks; this gravel must be carted from the best pit, near the south end of the lot. At the south end of the said bridge two hundred and sixty yards of gravel is wanted, four inches deep at an average. From thence to the termination of the section, the road requires a close covering of gravel on the hollows and wheel-tracks, which must be carted from the pit north of the Fir-wood, and the pit a little north of Car bridge; and at both ends of an eight-feet arch fifty yards of gravelling is required, to the average depth of ten inches, with a turf border to keep it in.

All the defective parts of the section, though not particularly described, are to be repaired by filling up all the hollows with good gravel, so that the whole may be left in perfect condition.

The watercourses are to be cleared out, the side and back drains to be made wider and deeper, and four bridges must be pointed and repaired where necessary.

Section II.

Extends from Carr bridge to Aviemore. The road from near the commencement to the Fir-wood is soft, and requires a covering of gravel carted from the pit at the north end, and laid over it to the depth of four inches. From thence to the first bridge in the wood, the outside of the road is too low, and requires a turf border, with a corresponding quantity of gravel, for about half the breadth of the road. From thence through the wood the surface is much worn, and the defects must be repaired in the manner above described, but at the south end of the wood the road must be covered with gravel four inches deep, for a distance of four hundred yards. From that point to the end of the section, the road being on a hard bottom is at present in good condition, but in course of the present repair will require all the hollows and tracks to be filled up with durable materials, and the surface left smooth and regular. All the rubbish on the upper side of the road, and on the slopes above the drains, must be thrown over the lower side of the road, and the watercourses made wider and deeper.

Section III.

Extends from Aviemore to Pitmain. From the commencement to the side of Loch Alvie, the road in several places is too flat, and requires a covering of gravel laid over it, to make the surface regular, to the depth of four to six inches; but before this is laid on, the large stone and points of rock must be removed, and twelve yards of retaining wall must be rebuilt, and the earthen mound repaired and raised to the height of two feet six inches above the surface of the road-way.

From Loch Alvie to the south approach of Kinrara the road is generally flat, and requires a close covering of gravel, to prevent the water from lying on the surface, or running along it; and from thence to opposite Ballnespeck the road is pretty good, but a few patches of gravel will be required on the hollows.

From last point to the side of Loch Inch, being about a mile, the road surface is soft and muddy, and requires a close covering of gravel all the way, in some places to the

depth of four inches, with a turf border along the sides. The road is pretty good by the side of the lake; but at the east march of Belleville four hundred yards must be gravelled, to the average depth of four inches, with materials carted from the pit south of the march, or boundary of the Belleville property.

From the milestone north of the porter's lodge to the square of Belleville, the surface is soft and irregular, and will require gravel all the way, to the average depth of three inches; these materials must be carted from the pit in the wood, or that at the burying-ground.

From thence to the milestone north of Kingussie, the road requires some patches of gravel on the hollows; and from that point to the bridge at the south end of the village, being about a mile, the surface is flat and soft, and requires gravel all the way, to the average depth of three inches. From that point to the bend in view of Pitmain, the surface is loose, and requires a covering of binding gravel laid over it. From thence to Pitmain the road is pretty good, but may require some gravel laid on the outside where it is low. The watercourses throughout the whole section must be carefully cleared out, and the rubbish thrown over the lower side of the road. All the seven bridges in this section require some trifling repairs in coping, and the open joints to be neatly pointed. The old retaining wall along the side of Loch Inch is partly fallen down, and must be rebuilt to its former height and dimensions, for twenty yards in length.

Section IV.

Extends from Pitmain to Dalwhinnie. From the commencement of the first twenty feet arch, being about a mile, the road in general is too flat, and is cut from two or three inches deep, and it now requires a close covering of sharp gravel over the carriage-way to the depth of two inches. From thence to Spey bridge all the hollows are to be filled up, and the surface left smooth and regular. The open joints of Spey bridge, and the twenty-feet arch north of it, are to be neatly pointed with good mortar. From thence proceeding southward for about two miles, the surface is at present in pretty good condition, but requires patches of gravel upon the hollows to preserve the proper form. From the corner of the stone fence, proceeding southward for one thousand yards, the road is soft, and requires four inches of sharp gravel all the way; it must be carted from the pits at each end of the distance, and two new cross drains of twelve inches must be made.

From the north end of the wood to the new improvement, the road at different places requires a close covering of gravel to bring it to the proper shape. Along the approaches to and from Etteridge bridge the hollows and wheel-tracks are to be made up with fresh materials; six yards of stone breast-work must be repaired, and the stones which protect the banks on the lower side are to be replaced. The pier of Etteridge bridge has been injured by the ice and floods, and must be repaired, by replacing all the loose stones, and pointing the whole pier with Parker's cement; and a pavement is to be laid round the foundations six feet broad, at least twelve inches in depth, and firmly wedged together. In front of the west abutment a paving is to extend for the whole length of the abutment and water-walls; it is to be three feet in breadth, and the stones laid in the same manner as round the pier; but before this is done, those parts of the

water-walls now tumbled down must be rebuilt to the original dimensions, and the outside stones laid in good mortar. Between the south approach and Pressmucrack, two cross drains of twelve inches each, and sixty yards of gravel, twelve inches average depth, are required, and at the second mile-stone north of Dalwhinnie, four hundred yards of gravelling is required, six inches deep, with a turf border to retain it, and two cross drains of twelve inches, with sixty yards of back drain.

From thence to Little Dalwhinnie, the stones on the surface are to be picked up, and the hollows filled with good gravel; the upper end of a double drain must be repaired, the bottom secured, and at both ends gravel is to be laid for one hundred yards in length and four inches in depth. From thence to the end of the section, the river Truim occasionally sweeps the gravel of the road, and leaves the large stones; it must now be covered with gravel all the way, in some places to the depth of three inches, and have a turf border where necessary. At the houses of Dalwhinnie, the road must be gravelled for one hundred yards in length and four inches in depth, and at the south end of the section three bridges of different sizes must be repaired and pointed.

Section V.

Extends from Dalwhinnie to the thirty-feet arch south of Steward's house. The road, from the commencement to the bridge of two arches, is generally too flat, and must be made up with good gravel; and ten yards of turf breast-work, now fallen down, must be rebuilt of stone. A little south of said bridge one hundred and sixty yards of gravel, six inches deep, is required, and a cross drain of eighteen inches and one of twelve inches must be repaired. From the bridge of two arches to the eighteen-feet arch, all the small gravel carried off by the winter storms is to be replaced, and the hollows and tracks filled with good gravel. In this distance, the watercourses of two ten-feet arches must be cleared out, the copings pointed, and ten yards of water-wall built to one of them. The watercourse of the eighteen-feet arch must be cleared out for a considerable distance above the bridge, and ten yards of bulwark built, to protect the road from injury. A little south of said bridge the water sometimes covers the road, which must be prevented by two cross drains of twelve inches, with sixty yards of embanking of eighteen inches average depth; the materials are to be taken from the irregular heights on the road. A little north of Steward's house, two hundred yards of gravelling will be required, at different places, four inches deep, and all the hollows made up with fresh materials; the loose rubbish on the slopes of the road-sides, in this and the foregoing sections, must be removed, and the side, cross and back drains effectually cleared out, and deepened. On this road two guide-posts are to be placed, the one at Little Dalwhinnie, pointing the road to Fort Augustus and Fort William on the one side, and Pitmain, &c., on the other side. The other is to be placed at the junction of the Laggan road, near Spey-Bridge, pointing westward, and lettered "Loch Laggan Road." The posts are to be of the same dimensions as those on the Corryarrick road, and neatly lettered and painted.

General Observations.

Through the whole of this line of road, it must be observed that all the loose stones, earth or rubbish in or about the side, covered or back drains, must be thrown over the

lower side of the road, and every obstruction between the abutments of the bridges removed. Where new gravel is to be used, it must be of a proper binding quality, and the stones mixed with it broken to the size of four ounces; but before it is applied, the old surface shall be so loosened with a pick, that the old and new gravel may incorporate together; and in all cases the road is to be maintained at this proper breadth, and have a turf border where necessary. The cross drains, breast or retaining walls, to be built or repaired, must in all cases be executed agreeably to the general specification for Highland Roads and Bridges, and over the covered drains, both old and new, a sufficient covering of gravel is to be laid at least six inches deep, and continued on each side, so as to occasion no irregular rise on the road. The back drains are to be every where three feet wide at top, one foot at bottom, and of sufficient depth to carry the water to the nearest bridge or covered drain. In all places where the road surface is lower than the adjoining ground, proper off-lets must be made, at the distance of thirty or forty yards apart, to carry off the water; they are to be from two to three feet wide, and of sufficient declivity to drain the road; and all the trees and brushwood which overhang and overshadow the road must be cut away.

The contractor is to observe, that he is to fill up and level, to the satisfaction of the inspector, all gravel-pits which may be made in arable land, or so near to the road side as to create any danger to travellers. The lime mortar used for the bridges and parapets must be of a proper quality, mixed with clean sharp sand, and the workmanship performed in a neat and substantial manner, before the first day of September next.

APPENDIX (L. 8.)

AGREEMENT for the REPAIR and IMPROVEMENT of a MILITARY ROAD: (STRATHSPEY to PITLOCHIE.)

SECTION I.

THIS section commences at the march of Strathgray, and terminates at the four-feet arch, nearly opposite the sixteenth milestone at the entrance of the Pass of Killicranky, measuring in all 4,440 yards.

The road through this division varies from fifteen to twenty feet in breadth; but by the present repair, it must all be reduced to eighteen feet; that is to say, the metal and gravel must in all places be laid to the breadth of sixteen feet, and have a border of green turf on each side to keep it from falling into the side drain. In cases, however, where the present road is of greater breadth, it is not to be diminished, but the metal or gravel is to be laid along the middle to the breadth of sixteen feet, in the manner pointed out by the road overseer, and the space between the edge of the metal and that of the side-drain is to be regularly formed to the same shape as the other parts; but, instead of stone-metal, it may be covered with four inches of the best gravel which the neighbourhood affords; but previous to any metal or gravel being applied, the road must be brought to a

regular form for five hundred yards in advance, during which operation the following works must be performed:

1st. At the commencement of the section two covered drains, of eighteen inches each, are required, with one hundred yards embanking to the depth of eighteen inches; and near the same place another drain is to be repaired.

2d. Proceeding a little farther, another drain of eighteen inches must be built, and one of twelve inches made anew; and from thence to opposite the lime quarry, other two must be rebuilt, the one twelve and the other eighteen inches.

3d. Proceeding still southward, another drain of twelve inches is required, with one hundred and twenty yards embanking, twelve inches average depth. A little beyond that place, another drain is required, and a ridge to be reduced two feet at an average for seventy yards in length, and the materials applied at the west end. From thence to the burn of Ault Clun two drains of eighteen inches are required, with some cutting to form the road regular.

4th. The parapets on the twelve-feet arch on the burn of Ault Clun must be taken down, rebuilt eighteen inches thick, and that to the height of five feet six inches above the present roadway, including a coping of hammer-dressed stones set on edge, nine inches in depth, with close upright joints; after which, the road must be gravelled to the depth of two feet at an average, the materials to be taken from the south-east end, and the finished surface to form an inclined plane between the heights at each end of the bridge, and the sides of the embankment supported by stone breastwork, where required.

5th. A little beyond this bridge an awkward bend must be cut off, by building thirty yards of breastwork about ten feet below the present road, to the height of the finished surface, including a turf coping, and at the north-west end the height must be reduced for forty-four yards, and the materials applied in filling up the bend, &c. Proceeding a little farther on, another ridge must be reduced two feet, at an average, for sixty yards in length, and in that quarter four twelve-inch drains are required.

6th. From this point the road passes for about eight hundred yards between hedges and dikes, where its surface is lower than the adjoining ground, and excluded from the sun and air; consequently, no quantity of gravel would make a permanent road, especially as there is no declivity to carry off the surface water. In order to obtain a thorough repair, the road surface must first be regularly formed, and then paved with stones five inches deep in the middle, and four at the sides; over this a second stratum of stones, previously broken to the size of a four-ounce weight, is to be laid five inches deep on the middle and three at the sides, and over the whole a binding of gravel two inches deep on the middle, and one inch on the sides, and the whole of a durable quality.

7th. The thirty-feet arch of Aultgarnoch must be repaired, by adding three feet to the thickness of the north-east wing-wall, extending it thirty feet, and turning it to suit the road, after which the parapets are to be wholly rebuilt eighteen inches thick, and four feet high above the road, on the crown of the arch, and have new coping set on edge not less

than nine inches deep. When this is done, the roadway is to be gravelled two feet deep for one hundred yards in length, and to the breadth of twenty-four feet at the ends of the bridge, so as to make safe approaches. In ascending the hill from the bridge, the road opposite to Mr. Roster's house must be widened for about twelve feet, and the height reduced two feet at an average for forty yards in length. In proceeding farther up the hill, the road is only fifteen feet wide; the additional five feet must therefore be taken from the north-east side for one hundred and twenty yards, after which, the dike must be rebuilt of the present dimensions; here the road surface must be made regular, by reducing a height twelve inches at an average for sixty yards in length. A little farther on, another ridge must be reduced, for forty yards, eighteen inches, and the hollow at bottom filled up with the materials.

8th. The parapets of a sixteen-feet arch must be repaired and coped with turf, and eighteen inches of gravel laid over the roadway for forty-two yards. The parapets of a ten-feet arch must be repaired and pointed, and another bridge of sixteen feet; the parapets (one of which is destroyed) must be repaired, raised to the height of three feet above the roadway, and have a stone coping, as above described. In this last distance, four drains of twelve inches are required, with the necessary embanking and gravelling.

Having now described the different articles required in this section, it is to be observed, that when they are duly performed, and the road brought to a proper form, the whole surface (excepting eight hundred yards, as above described) is to be covered with durable gravel, properly separated from all improper mixtures, to the depth of twelve inches on the middle of the road, and eight inches at the sides; but before it is laid on, four inches of broken stone may be laid in the bottom, which will be allowed as part of the above quantity.

In preparing the gravel for this section, the sand must be separated from it by a harp, if necessary, and the stones found therein regularly broken to the size of a four-ounce weight, and mixed with the gravel before it is carted to the road.

The side-drains throughout the whole section are in general obliterated, or higher than the middle of the road, and in course of the present repair must be regularly cleared out, their bottoms made twelve inches wide, and six inches under the formed road, with their sides sloping at the rate of two to one, with proper declivity to carry the water to the nearest covered drain, and all the cross drains made agreeable to the General Observations.

Section II.

From the termination of the last section to the place of Tynegate, being about a mile, a six-feet arch near the commencement must be repaired, and all the loose pinnings relaid in fresh mortar. The parapets are to be repaired, and have a new turf coping. The broken parts of the road parapets must also be repaired, and made up to the original dimensions, and pointed with mortar. The parapets of an eighteen-feet arch now in ruins, must be rebuilt to the height of four feet, and have a coping of stone set on edge nine inches deep, and the roadway over the bridge gravelled twelve inches average depth, for one hundred yards in length. In this division six new twelve-inch drains will be required, and those already built must be properly cleared out and repaired.

The present surface throughout this section is rather irregular, and covered with large stones, but the bottom in general is firm. In course of the present repair, the soft muddy substance must be removed, and the stones or rocky points picked up and broken to the size of a four-ounce weight, and levelled into the hollows, which, when done for five hundred yards in advance, the carriage-way is to be covered with stone broken to the size of a four-ounce weight, to the depth of four inches, over which a binding of the best gravel to be found in the section is to be laid to the depth of one inch *only*. The metal and binding to be laid to the breadth of sixteen feet, and from thence to the sides of the present road is to be covered with four inches of gravel, as above described.

It is to be observed, that in all cases the road surface, when finished, shall have a convex curve of four inches, and, when necessary, a turf border shall be laid to keep in the fresh materials. The side and covered drains must all be made and carefully cleared out in the manner described in the foregoing section.

Section III.

From the termination of last section to the house occupied by Donald M'Rae, measuring two thousand nine hundred and sixty-eight yards, the road for all this distance is bounded by hedges, dikes, and full-grown trees, which exclude the sun and air; and the surface, during winter and wet weather, is conseqnently heavy and muddy, being cut from four to ten inches deep; and as no proper gravel can conveniently be got, the only effectual repair will be by using broken stone; but before that is done, the following works must be performed:

1st. Between the commencement of the section and the west approach to the house of Faslich, six new twelve-inch drains will be required, with the necessary embankments, and two others repaired, with proper openings through the lower fence at every two hundred yards to carry off the surface water.

2d. Between the west and east approaches to the same house a ridge must be cut down, three feet at an average, for eighty yards in length, and the materials applied in filling the hollows at the east end.

3d. The parapets of an eight-feet arch are to be repaired, and twelve inches of gravel laid over the roadway for fifty yards. Another arch of ten feet to be repaired and coped with turf.

4th. From the height north-east of the last arch to the ridge south of the east approach to Mr. Butler's house, the road is hollow, and requires gravel laid six inches deep, at an average, for two hundred yards, and in this distance four covered drains must be carefully repaired.

5th. Near the west end of the wood four heights must be reduced twelve inches at an average, for two hundred yards in length, and the hollows filled with the materials; and at both ends of a new-made drain the hollows are to be made up for one hundred yards with the materials taken from the height at the south end of it.

When these works are performed, and the whole surface brought to the proper form, by picking up all the stones, and filling the hollows with durable materials, the bed of the

road is to be covered with broken stone to the depth of four inches in the middle, and three at the sides, which, when done for five hundred yards in advance, a second stratum of stones broken before they are carried to the road is to be laid to the depth of three inches in the middle, and two at the sides; both layers to be of a durable quality, and laid to the breadth of sixteen feet, over which a blending of good gravel, separated from all soil, sand and stones above a four-ounce weight, is to be laid to the depth of *one inch*. As this part of the road is from sixteen to twenty-four feet wide, the sides may be dressed with a sufficient declivity to carry off the surface-water to the side drain, and the extra breadth between the metal and side drain may be gravelled four inches deep; but it must be observed, that in forming the road and laying the gravel, the finished surface shall have a convex curve of at least four inches.

Throughout the section, side-drains must be made on each side of the road, and close by the bottom of the dikes, and finished in the manner described in the foregoing section, with proper passages through the dikes at all places where necessary to take off the water.

Section IV.

From the termination of last section to the junction with the Mouline road, south of Pitlochie, measuring two thousand and twenty-four yards, the breadth of the present road through this division varies from fifteen to twenty feet; but as the narrow places are not confined by fences, it must in all places be formed to the width of eighteen feet, and in doing so, the following works must be performed:

1st. Below John Macdougal's house the cross drain must be repaired, and its length extended to the dike on the lower side of the road; after which, the road is to be raised two feet, at an average, for seventy yards in length, and two additional new drains made near that place.

2d. From thence to the village of Pitlochie the road is narrow, and generally too flat on the middle, especially for about five hundred yards opposite the blacksmith's shop and buildings, but the gravel found in widening it may be laid in the middle to bring the road to the proper shape.

3d. The parapets of a ten-feet arch must be repaired and pointed, and the coping renewed. From the top of said arch, proceeding southward, the road must be raised two feet, at an average, for sixty yards in length.

4th. The parapets of the eighteen-feet arch at Pitlochie must be repaired, the ends of them raised for eighteen inches, and all the open joints of the bridge neatly pointed. From the height north-east of the inn to the rising ground south of the buildings, a distance of two hundred yards, the road must be embanked to the average depth of two feet; and from the ends of the bridge, the sides of the embankment are to be supported by stone-work; but as an upright wall would be inconvenient to the inhabitants, the embankment may be made twenty-four feet wide at top, and the sides secured by a flat pavement made with stones not less than six inches in depth, sloping at the rate of three to one.

5th. Near the south end of the division an inconvenient height must be reduced three feet at an average, for one hundred and twenty yards in length, and the materials deposited in the hollow south of it, still leaving the road eighteen feet wide.

When the whole section is brought to that breadth, and of the proper form, the surface is to be covered with gravel of a proper binding quality to the depth of six inches on the middle, and four at the sides; this gravel must be properly cleansed from sand and soil, but the stones found in it may be broken to the size of a four-ounce weight, and mixed with the gravel. It is to be laid to the breadth of sixteen feet, and have a turf border at least twelve inches broad to keep it in.

On each side of the road, side drains are to be made of the dimensions formerly specified, with the necessary back drains, which will be pointed out. The whole covered drains in the section must be regularly cleared out, and repaired in a sufficient manner; besides those now made, four new drains of twelve inches will be required.

General Observations.

In repairing this road, it must be observed, that the breadth of the metalled or gravelled carriage-way shall in no place be less than sixteen feet; and along those places where it is formed anew, it must be executed in the manner already described, all exclusive of the side drains.

The whole of the side, back and cross drains are to be thoroughly cleared out, and all the loose earth, rubbish, stones and gravel in or about them must be thrown over the lower side of the road. In all places where metal is used, the stones must be of a proper quality, and no land stones, or pebbles taken from gravel-pits, are to be laid on or mixed with the upper stratum till they are first broken to the size above specified, and that they will, in their largest dimensions, pass through a ring of two inches diameter. In all places where gravel is to be used, it must be of a proper binding quality, separated from all soil, sand, or other improper mixtures; but the stones found in it may be properly broken in the pits to the size, and pass through the ring above specified, and mixed with the gravel which is to be laid on the carriage-way.

Where cross drains are to be made, their sides are to be regularly built with dry stones, not less than twelve inches in thickness; their bottoms to be paved with stones set on edge, not less than four inches deep, with a fall of at least twelve inches in the breadth of the road, and covered with flag-stones, in no place less than four inches thick, laid with close joints over the whole opening, and to have a hold on each of the side walls of at least six inches. These cross drains shall be so laid out as to have from eight to ten inches of metal or gravel over the covers, and their ends made sufficiently capacious, and secured with pavement. Where back drains are necessary, they are to be cut at all places where the inspector points out; they are to be three feet wide at top, one foot at bottom, and of a sufficient depth effectually to carry the water to the nearest covered drain.

When breast or retaining walls are to be built, they are to be executed in all respects agreeably to the general specification for Parliamentary roads. The lime mortar to be used in pointing or building any of the bridges must be of a good quality, mixed with

clean sharp sand, and the workmanship performed in a substantial and workmanlike manner, and in the proper season.

Intending contractors must observe, that during the execution of the work, they must at all times keep the road in a safe, passable state for travellers, and that in making the cross drains, or reducing heights, one-half of the road must be made passable for carriages before the other is begun; and that they are to be liable for any accident that may happen from inattention or neglect on their part; and they are to leave no heaps of gravel or stone on the road without being levelled down when discharged from the carts.

The contractors are to slope down or fill up all gravel pits which they may make so near the road side as to occasion any danger to travellers; and the whole work upon all the fore-mentioned sections must be performed agreeably to this specification, and in a regular and workmanlike manner, to the entire satisfaction of the inspector who may be appointed to oversee the work; and these general remarks are applicable to the whole sections between Bruar bridge and the Mouline road.

Appendix (L. 9.)

AGREEMENT for the Improvement of a portion of County Road, forming part of the Great North Road.

(Beauley to Ross-shire Boundary.)

The present state of this road, and the repairs required thereon, being different in different places, it has been judged convenient to divide the line into sections, as follows; viz.

Section I.

From the end of the paved street of Dingwall, southward, to a little west of the gate leading to Mr. M'Rae's farm, of Humberston, measuring one thousand five hundred and forty yards. The road for this distance is from eighteen to twenty-two feet wide, about twelve feet of the middle of which has originally been metalled with broken stone; but, having been totally neglected for the last nine years, and daily exposed to heavy carriages, the metal in several places is completely worn, and the bottom being a deep loamy clay, the road at some seasons is scarcely passable.

In order to make the present repair effectual, it will be necessary to trench over the whole road for this distance, remove all the stones which are too large, and bring the bed of the road to the proper form for twenty feet in breadth; after which, for a breadth of eighteen feet, a stratum, six inches deep, of the best stone which can be procured from Dingwall quarry, which is near the middle of the section, is to be set on edge by hand in a regular manner, and all the inequalities of their tops broken off with a hammer, and filled with stone chips. When this is done for two hundred yards in advance, a second stratum of durable sand-stones, broken so small that none shall exceed four ounces weight, is to be laid over the first, to the depth of six inches on the middle, and three inches at the

sides of the road; and over this last a binding of durable gravel, carted from the bed or banks of the river Conon, is to be laid to the depth of two inches on the middle, and one at the sides. As this part of the road is chiefly bounded by stone fences on each side, turf borders will be unnecessary, but side drains are indispensable; they must in all cases be made in a regular manner, eighteen inches wide at bottom, which bottom shall be at least eight inches lower than the middle of the carriage-way, and to slope on the side next to the road, at the rate of two to one; but where the breadth between the fences does not admit of this slope, the drain may be of one to one; but in the last case the sides and bottom must be paved with stones set on edge, not less than four inches deep.

The whole of the covered drains now made are to be properly cleared out, three of eighteen inches made anew, and one of two feet effectually repaired.

The carriage-way into Dingwall for about two hundred yards is only twelve feet wide, its breadth having been diminished by opening a drain along the road-side to carry off some stagnant water; but, in order to obtain the breadth of twenty feet, this drain must be built and covered in a proper manner, and the lower end cleared out, so that the water may pass along it without interruption.

Section II.

From the termination of last section to the bridge of Maryburgh, measuring nine hundred and forty-six yards. From the end of last section, onwards for six hundred and forty-six yards, the road has been formed and metalled, as above described; but the stones on the surface being large and irregular, they must be reduced to the before-mentioned size, and the hollows, where the metal is deficient, are to be made up with fresh metal to the depth of ten inches on the middle of the road; as the metal is only twelve feet wide, three feet of additional breadth is to be added to each side, to the depth of eight inches. The materials are to be taken either from the land, or from the bed of the river Conon, and broken to the proper size; this depth of metal is considered sufficient, as the road for this distance is on a hard bottom.

For about three hundred yards next to the bridge the old metal is completely worn out, and will require a new covering, laid to the full depth of twelve inches in the middle of the road, nine at the sides, and to the breadth of eighteen feet; it must be laid in the manner described for the first section, and the stone of a durable quality.

The embankment at the north end of the bridge is too narrow and too low, and must be raised, for forty yards in length, to the average height of eighteen inches, to be twenty-four feet wide at top, the sides to slope at the rate of two to one, and covered with turf laid flat. When this is performed, and the metalling laid to the specific dimensions, the whole surface is to be covered with gravel, from the banks or bed of the Conon, to the depth of two inches in the middle, and one at the sides of the road; the side drains and cross drains are to be cleared out and repaired. The parapets of the bridge are too low, and partly destroyed; they must be rebuilt three feet above the surface of the finished roadway, including a coping of hammer-dressed stones set on edge, and the ends of the parapets turned down under the road surface, and the whole of the bridge is to be neatly

pinned and pointed. The channel of the water above the bridge must be cleared out, and the stream conducted into the arch in a regular manner.

SECTION III.

Extends from the end of the last division to the north end of the parapets of Conon bridge, and measures eleven hundred and twelve yards. The embankment at the south end of Maryburgh bridge, at the commencement of the section, is too low and narrow, and must be raised for ninety yards in length to the average height of fifteen inches; the breadth must also be extended on each side, so that it shall be twenty-four feet wide at top, and the sides, sloping at the rate of two to one, are to be covered with turf laid flat. The materials for this purpose are to be taken from the rising ground above George Stewart's house, which will considerably reduce a very inconvenient hill. When this is done, the road must be metalled afresh for two hundred and thirty yards from the bridge, to the depth of ten inches in the middle and eight at the sides, and to the breadth of eighteen feet.

From thence to Conon bridge the metal is at present only about six inches deep, and the stones in general are too large, with irregular hollows on the surface; the large stones must be broken, the hollows filled with broken metal, and the additional quantity laid on to bring the whole thickness to ten inches in the middle, and eight at the sides; the metalling must also be extended three feet on each side, after which a binding of river gravel is to be laid over the surface to the depth of two inches on the middle, and one on the sides.

In this section the sides of the road are from twelve to twenty inches too low, and must be raised to the proper form. Part of the materials for this purpose will be procured in widening the metal box, and the remainder must be taken where most convenient.

The side-drains must be properly cleared out and finished, as described in the first section; one new drain of eighteen inches is to be made, one rebuilt, and one repaired, and those already made are to be cleared, their entrances paved, and the channels to and from them made wider and deeper.

From the north end of Conon bridge, southwards, for six hundred and sixty yards, the road passes along the bridge and part of the Fortrose line, which is now in good repair; it is not included in the estimate, but constitutes a part of the total length of the road.

SECTION IV.

From the junction with Fortrose road, proceeding onward to the gate pillars at the west end of the old blacksmith's shop, measuring two thousand six hundred and forty yards. The road for this distance has been formed to the breadth of twenty-four feet, of which twelve feet in the centre has been metalled with stone, which remains pretty regular; and as the sides in general are only from nine to twelve inches below the centre, the road may be made sufficiently good, by confining the breadth to twenty feet, and laying two inches of gravel on the centre, and nine inches at the sides; but, previous to this being done, the present surface must be brought to the proper form for two hundred yards in advance; so that, when finished, it may have a regular convex curve of four inches.

A border of double turf, twelve inches broad, is to be laid in a regular manner along each side, battering on the outside at the rate of two to one; and, to preserve the border from injury, the stones raked from the gravel are to be laid on the top of it.

The watercourses, which have been neglected for nine years, are completely choked, and must all be thoroughly cleaned out. The side-drains are to be made eighteen inches wide at bottom, with their sides sloping at the rate of two to one, and their bottoms fully eight inches lower than the centre of the roadway. One covered drain of eighteen inches must be rebuilt, and other two repaired.

As no gravel of a proper quality can be had in the vicinity of the road, it must all be carted from the bed or banks of the river Conon, or from some other place of equally good quality.

One bridge of eight feet span requires pinning and pointing, with a new coping of hammer-dressed stones set on edge, at least nine inches in depth, and these ends turned down to the road surface. Two other bridges of seventeen feet span each require pinning and pointing, and the broken parts of the parapets repaired.

Section V.

From the end of the last section to the ten-feet arch, nearly opposite Highfield, measuring two thousand one hundred and thirty-four yards, the road for the whole of this division has been formed and metalled to the same breadth as the foregoing; but the sides being composed of softer materials, have sunk from one to two feet lower than the centre, leaving a narrow ridge, covered with large loose stones, for the carriage-way.

In repairing this section, the breadth must be reduced to twenty feet, by laying borders of green turf at that breadth, with a batter on the outside of two to one, and raised to within four inches of the middle of the finished road, after which all the large stones appearing on the surface are to be collected and reduced to the before-mentioned size, and the hollows filled up with proper materials, and brought to the regular form, to within nine inches of the top of the turf-borders.

When this is performed for two hundred yards in advance, the whole surface is to be covered with gravel of a proper binding quality, previously separated from all improper mixtures, to the depth of two inches on the middle of the roadway, and nine inches at the sides.

One drain of twelve inches is to be rebuilt, and all the covered drains cleared out, and paved at the ends, and the watercourses to and from them made wider and deeper.

The ten-feet arch at the termination must be pinned and pointed, the coping (now partly destroyed) re-laid on edge, at least nine inches in depth, and the watercourse to and from the bridge cleared out for twenty yards.

Section VI.

From the ten-feet arch to the west side of the fir-plantation, measuring one thousand nine hundred and thirty-six yards. The road for this distance is formed and metalled similar to the foregoing sections, and the sides are from four to eighteen inches lower than the middle of the road, and will require to be repaired, by laying turf borders, at the breadth of twenty feet, with a covering of gravel two inches deep in the middle of the road, and nine inches at the sides; but before applying the new gravel, all the large stones on the surface

are to be duly broken, and the hollows made up as described in the former sections, and the watercourses cleared out, and made of the same dimensions and form as therein directed; the covered drains require also to be cleared out, and paved at the ends, and the passages to and from them widened and deepened.

Section VII.

From thence to the junction with the Beauley road, at the twenty-feet arch at Aultnabracht, measuring two thousand one hundred and thirty-four yards. The road for this distance has originally been formed and metalled similar to the foregoing sections; but the bottom being of a sandy, soft nature, the road-sides are composed of that material, and have wasted and sunk from eighteen to twenty-four inches lower than the centre, leaving a narrow, stony ridge for a carriage-way.

In repairing this section, the whole of the large stones on the surface must be collected, and regularly reduced to the specified size, the irregular hollows on the surface and sides made up, and brought to the proper form; after which, turf borders are to be laid at the breadth of twenty feet, and gravel of a durable quality laid on to the depth of two inches on the middle of the road, and nine inches at the sides, still leaving a convex curve of four inches from the centre to the sides. Along this part of the line, proper side-drains must be made, of the dimensions before specified, and at such a distance from the side-turfs as to prevent any injury thereby.

Through the whole of this and the fifth section, no proper gravel can be had by the road-sides, but it can be procured in the neighbourhood of the sixth section. The contractor must calculate on carrying the whole that may be required for the last three sections from the best pits that can be discovered in that quarter. This will, no doubt, be expensive; but it is vain to attempt repairing roads with improper materials; the expense is increased, without giving satisfaction.

In repairing this road, it is to be formed every where to the breadth of twenty feet in the clear, including the breadth of a turf border on each side, which are to be laid in all places where the breadth between the fences will admit of them, and the side drains of the dimensions before specified, that is to say, they are to be eighteen inches wide at the bottom. The gravel to be used on the road must be all of a durable quality, separated from all stones above the size of four ounces weight; it must be perfectly cleared of all improper mixtures, and laid to the specified depth. The large stones raked from the gravel are to be regularly laid along the top of the turf borders, to protect them from injury.

The mortar to be used in repairing and pointing the bridges must be composed of lime of the best quality, mixed with clean sand from the river, and the workmanship performed in a neat and substantial manner.

The whole of the work, both on the road and bridges, must be executed agreeably to the foregoing specification, and to the satisfaction of the inspector appointed by the commissioners. The contractor must calculate on keeping a regular, safe and commodious passage open for carts and carriages at all times during the execution of the work; that no heaps of stones or gravel are to be left on the road during the night, without being levelled down; otherwise he shall be liable for any accident that may happen.

(signed) *John Mitchell.*

APPENDIX (L. 10.)

DISTRICTS of the several INSPECTORS of HIGHLAND ROAD REPAIR, 1828.

1. ARGYLESHIRE DISTRICT.—*Robert Garrow*, Inspector.

Description and Names of Roads.	Length in Miles.	Rate per Mile. £.	s.	d.	Annual Expense. £.	s.	d.
PARLIAMENTARY ROADS:							
Arran Roads	17	4	–	–	68	–	–
Crinan and Keils Roads	4	4	4	–	16	16	–
Glendaruel and Riddan Roads	21	4	–	–	84	–	–
Islay Road	14 ¾	4	12	–	67	17	–
Jura Road	17 ⅛	3	–	–	51	–	–
Kilmelford Road	8 ½	3	15	–	31	17	–
Strachur Road	12	4	4	–	50	8	–
Ardnoe Road	6 ½	5	–	–	32	10	–
MILITARY ROADS:							
Dalmally Road	26	9	12	–	249	17	–
Glencoe Road	33	9	12	–	317	–	–
Glencroe Road	21	9	12	–	201	17	–
	180 ⅞	-	-	-	1,171	2	–

2. BADENOCH DISTRICT.—*George Macfarlane*, Inspector.

Description and Names of Roads.	Length in Miles.	Rate per Mile. £.	s.	d.	Annual Expense. £.	s.	d.
PARLIAMENTARY ROADS:							
Alford Road	13 ½	5	–	–	67	10	–
Ballater Bridge Approaches	– ½	-	-	-	25	5	–
Craigellachie Bridge Approaches	1	11	11	–	11	11	–
Findhorn Road	14 ⅝	6	10	–	85	15	–
Inverfarigaig Road (and Pier)	19	3	3	–	63	17	–
Loch-Laggan Road	39	5	–	–	195	–	–
Branch to High Bridge*	3 ½		—			—	
Moy Road	14 ½	10	5	–	149	2	6
Spey-side Road	14	5	–	–	70	–	–
Strath-Spey (near Abernethy)	2		—			—	
MILITARY ROADS:							
Badenoch Road	52	9	13	2	502	4	9
Coryarrick Road (part)	8	7	1	3	56	10	–
Extension eastward to Laggan Kirk*	22		—			—	
Duthel Road	6 ½	5	–	–	32	10	–
Grantown Roads	20	9	4	1 ½	184	2	6
	229 ⅝	-	-	-	1,443	7	9

* The old military bridges and frequent ravines on these roads are kept in a passable condition as cattle-tracks, not for wheel-carriages.

3. LOCHABER DISTRICT.—*Daniel M'Innes*, Inspector.

Description and Names of Roads.	Length in Miles.	Rate per Mile. £.	s.	d.	Annual Expense. £.	s.	d.
Parliamentary Roads:							
Ballichernoch Road	5	3	–	–	15	–	–
Fort-Augustus Road	6 ½	4	–	–	26	–	–
Glengarry Road	31 ¾	5	15	–	182	1	8
Glenmorriston Road	20	5	–	–	100	–	–
Invermorriston Road	21 ¾	7	–	–	152	5	–
Extension to Doughfour	2		—			—	
Rheabuie Road	10	4	16	–	48	–	–
Lochy-side Road	12	4	10	–	54	–	–
Lochnagaul Road, Section 1.	15	3	8	–	115	10	–
Lochnagaul Road, Section 2.	21 ½	3	–	–			
Moydart Road	35	3	–	–	105	–	–
Military Roads:							
North Boleskine Road	19	8	11	7	163		4
South Boleskine Road	14	4	7	3 ½	61	2	3
Fort-William Road	45	4	9	6 ½	201	8	10
	258 ½	-	-	-	1,223	8	1

4. SKYE DISTRICT.—*James Smith*, Inspector.

Description and Names of Roads.	Length in Miles.	Rate per Mile. £.	s.	d.	Annual Expense. £.	s.	d.
Parliamentary Roads:							
Ardelve and Lochalsh Roads	16 ½	4	15		78	7	6
Glenelg Road	12	4	16		57	12	–
Glenshiel Road	16 ½	4	16		79	4	–
Kintail Road	10	4	16		48	–	–
Isle of Skye Roads:							
Macleod's Road	19	4	10		85	10	–
Skye Roads — 117	73 ½	4	15		349	2	6
Snizort Road	25	4	10		112	10	–
	172 ½	-	-		810	6	–

5. ROSS-SHIRE DISTRICT.—*Robert Murray*, Inspector.

Description and Names of Roads.	Length in Miles.	Rate per Mile. £.	s.	d.	Annual Expense. £.	s.	d.
Parliamentary Roads:							
Beauley Road	15 ½	12	–	-	186	–	–
Contin Road	7	10	–	-	70	–	–
Fearn Road	23 ½	7	10	-	176	5	–
Fortrose Road	14	8	–	-	112	–	–
Kessock Branch Roads	8	6	–	-	48	–	–
Kishorn Road	15	3	5		48	15	–
Loch-Carron Road, Section 1.	33 ½	5	–		165	5	–
Loch-Carron Road, Section 2.	16	4	–		64	–	–
Strathglass Road	23 ½	5	–		117	10	–
Tain Road	15	6	6		94	10	–
Invergordon Road	18 ½	7	7		135	19	6
Dingwall Road	6 ¾	8	–		54	–	–
Military Road:							
Fort-George Road (Inverness-shire)	13 ¼	11			151	16	11
	209 ½				1,424	1	5

6. CAITHNESS and SUTHERLAND DISTRICT.—*Thomas Spence*, Inspector.

Description and Names of Roads.	Length in Miles.	Rate per Mile.			Annual Expense.		
PARLIAMENTARY ROADS:		£.	s.	d.	£.	s.	d.
Dunbeath Road - - - - - -	33	11	9	6½	378	15	–
Dunrobin or Coast Road - - - - -	47	9	9	9	445	18	–
Thurso Road - - - - - - -	20	9	5	4	194	12	6
Tongue Road - - - - - - -	49½	5	5	–	258	12	6
	149½	-	-	-	1,277	18	–

	Miles.
SUMMARY of PARLIAMENTARY ROADS - - - - - -	920
SUMMARY of MILITARY ROADS - - - - - - -	280
Six Inspectors have charge of - - - -	1,200

LOWLAND DISTRICT.—*John Pollok*, Inspector.

	Miles.
Glasgow and Carlisle Road - - - - - -	104
Cumbernauld Road - - - - - - -	41
Lanarkshire Road across the County (East and West)	39
	184

APPENDIX (L. 11.)

IMPROVED STATE of the HIGHLANDS of SCOTLAND by the Construction of ROADS, BRIDGES and FERRY-PIERS; with general Notices of the Results, as affecting the Agriculture, Commerce and Convenience of the Inhabitants of the HIGHLANDS:—being Extracts from Letters addressed to Lord *Colchester*, in January and March 1828, by Mr. *Joseph Mitchell*, Successor of his Father, Mr. *John Mitchell* [*see* p. 174], as Superintendent of Roads and Bridges in the Highlands of Scotland.

HAVING now completed the investigations necessary for enabling me to report on the various important improvements in the Highlands and Islands of Scotland, to which your Lordship had called my attention, I beg leave to submit for your Lordship's consideration the result of my inquiries and observations; in doing which I cannot adopt a more convenient arrangement than that suggested in your Lordship's letter.

It may not appear unimportant to state, that in acquiring the fullest information on the several subjects to which I shall have occasion to advert, I have consulted with proprietors and other individuals, who, from their intimate connection with, or knowledge of, the

districts where improvements are called for, might throw such additional light on them as to enable me to judge more correctly of their local expediency and practicability.

ROADS.

In this department I shall, as briefly as possible, take a general review of the present condition of the Parliamentary and Military Roads under the management of the Commissioners, distinguishing the Six Districts into which they are distributed. For this purpose, it will be proper, both for the sake of brevity and of perspicuity, to arrange the roads comprehended in each, with their lengths, and the present expense of keeping them in repair annually, in a tabular form; subjoining such remark as it will be necessary for me to offer on each district respectively, and stating what occurs to me as advisable to be done on the several lines, in so far as regards partial repair and improvement.

1st.—ARGYLESHIRE DISTRICT.—*Robert Garrow*, Inspector.

Description and Names of Roads.		Length in Miles.	Rate per Mile.			Annual Expense.		
			£.	s.	d.	£.	s.	d.
Parliamentary Roads	Arran Road - - -	17	4	–	–	68	–	–
	Crinan and Keils Roads -	4	4	4	–	16	16	–
	Glendaruel Roads - -	21	4	–	–	84	–	–
	Islay Road - - -	$14\frac{3}{4}$	4	12	–	67	17	–
	Jura Road - - -	$17\frac{1}{8}$	3	–	–	51	–	–
	Kilmelford Road - -	$8\frac{1}{2}$	3	15	–	31	17	–
	Strachur Road - -	12	4	4	–	50	8	–
	Ardnoe Road - -	$6\frac{1}{2}$	5	–	–	32	10	–
Military Roads -	Dalmally Road - -	26	9	12	–	249	17	–
	Glencoe Road - -	33	9	12	–	317	–	–
	Glencroe Road - -	21	9	12	–	201	17	–
		$180\frac{7}{8}$				1,171	2	6

With the exception of the military roads in this district, the other roads enumerated have been constructed under the direction of the Commissioners, at different periods since the passing of the Act of 1803, and no particular improvement appears necessary on them. They have since been regularly kept in repair under the same management, and are found fully to answer the expectations and purposes contemplated in their original formation.

In 1815, the county of Argyle applied to the Commissioners to take charge of the military roads, extending from the ferry of Ballachulish, through Glencoe, Tyndrum, Inverary, and the valley of Glencroe, to the confines of the county of Dumbarton, a distance of about eighty miles; and the arrangement of such charge was finally agreed upon in the following year. Argyleshire Military Roads.

At this period these roads were very defective for the purposes of civil communication, there being few or no covered drains built for conveying the water across the road; and Defects.

the surface had no regular form, abounding in holes from eighteen inches to two feet deep, and in many cases covered with large stones.

Although in general the direction was circuitous, awkward, and injudiciously laid out, and the ascents exceedingly steep, the great object, on the Commissioners taking charge of these roads, appears to have been the renovation and repair of the surface, which certainly in a considerable degree diminished the inconvenience of the greater defects; but it is likely that the expense was then considered too great to effect any more extended improvements.

From that time these roads were carefully attended to, and many valuable repairs on the surface were effected until 1826, when all had been done which was necessary to form a smooth and regular surface, and it afterwards seemed only requisite to preserve them in that state. Still, however, in consequence of their awkward direction and very steep ascents, the winter-torrents are liable to create much damage; and until these inconvenient parts are avoided, accidents will constantly occur, and the annual expense of repair (now considerable) will be undiminished; not from the extent of traffic, but from the constant supply of materials necessary for the renewal of the surface, after continued and heavy rains.

2d.—BADENOCH DISTRICT.—*George Macfarlane*, Inspector.

Description and Names of Roads.		Length in Miles.	Rate per Mile.			Annual Expense.		
			£.	s.	d.	£.	s.	d.
Parliamentary Roads	Alford Road - - -	13 ½	5	–	–	67	10	–
	Ballater Road Approaches	– ½	-	-	-	25	5	–
	Craigellachie Road Approaches - - -	1	11	11	–	11	11	–
	Findhorn Road - -	14 ⅛	6	10	–	85	15	–
	Inverfarigaig Road (and Pier) - - - -	19	3	3	–	63	17	–
	Loch-Laggan Road -	39	5	–	–	195	–	–
	Moy Road - - -	14 ½	10	5	–	149	2	6
	Spey-side Road - -	14	5	–	–	70	–	–
Military Roads -	Badenoch Road - -	52	9	13	2	502	4	9
	Coryarrick Road - -	8	7	1	3	56	10	–
	Duthel Road - - -	6 ½	5	–	–	32	10	–
	Grantown Road - -	20	9	4	1 ½	184	2	6
		202 ⅛				1,443	7	9

Loch-Laggan Road.

On the Parliamentary roads of this district no essential improvements are necessary, with the exception, indeed, of the Loch-Laggan road, which, although a valuable branch of communication, is rendered almost useless from the want of a bridge over the Spey at Laggan-Kirk, and of an inn between Keppoch and Pitmain, a distance of upwards of thirty miles. Arrangements, however, which I shall afterwards explain, have been made for supplying the former of these defects; and it is confidently expected that, from the

recent accession of the present Duke of Gordon, so necessary an accommodation as the latter will no longer be overlooked.

Military Roads. Coryarrick Road.

The Duthel and Grantown military roads are valuable lines of communication in the populous and improving valley of the Spey; but the northern part of the Coryarrick road, from Laggan-Kirk to Fort Augustus, has been abandoned for upwards of a year, since the completion of the improvement on the Fort William road to avoid High-bridge; in consequence of which that mountainous and rugged line will now, for almost every purpose of general intercourse, be entirely superseded by the Laggan road. The bridges, however, are maintained, on account of their occasional accommodation as a passage for cattle.

Badenoch Road.

The first fourteen miles of the military road from Inverness to Perth were altered and widened at an early period of the operations of the Commissioners, and became a Parliamentary road, by the name of the Moy road; but the other portion, extending to the boundary of Perthshire, remained in its original condition until 1815, when it also came under their management. Since that time it has been very greatly improved on the surface, and some alterations of considerable importance have been made, particularly at and near Spey bridge, and at Drumochdar; but it could not be expected that, with the limited annual allowance for the repair of this road, any extensive improvement could be accomplished. What has been done, however, has been attended with beneficial consequences; and, as an instance, I may mention that the Caledonian coach, which formerly with difficulty travelled from Inverness to Perth in three days, is now with ease enabled to perform it in one. Yet, from the unprotected and precipitous ascents, the narrowness of the road, and the numerous acute angles, accidents may occur; and in the event of its being found inexpedient to make entire alterations in a shorter direction, the expense of rendering this road completely safe and commodious for travelling cannot be estimated at less than £. 12,000.

3d.—LOCHABER DISTRICT.—*Daniel M'Innes*, Inspector.

Description and Names of Roads.		Length in Miles.	Rate per Mile. £. s. d.	Annual Expense. £. s. d.
Parliamentary Roads	Ballachernoch Road	5	3 – –	15 – –
	Fort Augustus Road	6 ½	4 – –	26 – –
	Glengarry Road	31 ¾	5 15 –	182 1 8
	Glenmorriston Road	20	5 – –	100 – –
	Invermorriston Road	21 ¾	7 – –	152 5 –
	Rheabuie Road	10	4 16 –	48 – –
	Lochy-side Road	12	4 10 –	54 – –
	Lochnagaul Road, Sect. 1st & 2d	15 21 ½	3 8 – 3 – –	115 10 –
	Moydart Road, Sect. 1st, 2d & 3d	35	3 – –	105 – –
Military Roads	North Boleskine Road	19	8 11 7	163 – 4
	South Boleskine Road	14	4 7 3½	61 2 3
	Fort William Road	45	4 9 6½	201 8 10
		256		1,223 8 1

The lines in this district are peculiarly important, as opening up the most inaccessible parts of the Highlands; but as many of them were constructed early, there has been less attention paid to their general inclinations than in others more recently formed. This is, indeed, of less consequence, as they are principally useful for local intercourse; although some form exceptions to this remark. The Invermorriston or Loch-Ness-side road joins at Fort Augustus part of the great military road to Fort William, and with the Glenmorriston road, through the valley of that name, forms part of the principal line of communication from Inverness to the Western Islands.

Invermorriston Road.

The construction of the former (or Invermorriston) road must have been originally extremely difficult; in some parts it has, for its whole breadth, been cut out from the solid rocks, and where these rocks were nearly perpendicular, breast-walls of considerable height have been built, on which the road is formed for a great extent. Indeed, having such difficulties to contend with, it was not to be expected that the most perfect line could, in the first instance, be obtained; and consequently there are many parts, where the acclivities are both steep and inconvenient, that admit of alteration and improvement. Those which require most attention are about two miles and a half westward of Urquhart Castle, an ascent about a mile westward of Portclair, and the dangerous descent of the road towards Bun-Oich and Fort Augustus.

On the most unprotected portions of this line parapet-walls have been built for several miles in length; but there are still many parts that ought to be protected, which, however, the limited state of our repair funds has hitherto prevented from being done.

Torvaine Road.

The northern part of this road, next the town of Inverness, was made by the Caledonian Canal Commissioners, in consequence of the old road being occupied by the line of that canal; and this portion of road remains in charge of the District Trustees, but from their inattention, or other causes, is kept in inferior order. It would be highly advantageous to the public that the entrance to the town of Inverness upon this line, which is at present crooked, narrow and inconvenient, should be altered and improved.

Had not the Caledonian Canal been opened, the great traffic on this road would have demanded immediate attention to all the improvements and alterations mentioned; but a great portion of the general intercourse is now effected with so much ease by the navigation on the canal as to have reduced the traffic considerably; and I should deem it unnecessary to make any alterations beyond what I have mentioned above. These would render the road safe, and the surface has always been kept smooth, which may be considered sufficient accommodation for all the travelling on it.

Military Roads.

Fort William Road.

The military road on the opposite side of Loch Ness, from Inverness to Fort Augustus, for the same reasons, requires no further attention than the preservation of its surface in its present good condition; but the continuation of that line westward of Fort Augustus to Ballachulish is still important, as being the direct route southward for all travellers from Skye and the other islands, as well as from the several valleys which branch from the great Caledonian glen; and it is also the road by which numerous droves of cattle and sheep pass to the southern markets.

An important improvement on this line has been completed about a year ago, in the construction of about three miles of road to Spean bridge, to avoid the steep approaches to High-bridge, which is now falling and in a dangerous condition; but another alteration, equally necessary, is yet wanted at the dangerous descent to Low-bridge, which is exceedingly awkward in its direction, and in some parts so steep as one in four. Indeed this latter was considered so essentially requisite, that a survey of it was made, and a plan prepared for it about two years ago. Improvement at Low-bridge.

An improvement is also needed, with a bridge of about twenty feet span, about two miles north of the ferry of Lochy, where the road has been made across very irregular ground, occasioning a succession of short but very steep ascents and descents. To obviate these defects, an entire alteration would be necessary here for a mile in length. Improvement north of Lochy-Ferry.

There is a still further impediment to travelling on this road which ought to be mentioned, and which seems to call for immediate attention. By the operations on the Caledonian Canal about two years ago, and during a continuance of severe storms, Loch Lochy rose considerably above the usual level; by which the road for several miles along the edge of the lake, supported at intervals by bulwarks of masonry, was very greatly injured, and in many parts wholly destroyed. Immediate measures were taken for repairing it in a temporary manner, and it has since been kept barely passable at the expense of the Caledonian Canal; but as the causes which raised the lake to such a height are now removed, it is desirable that this road should be repaired in an effectual and permanent manner. Damage at Letterfinlay.

When these improvements are executed, I should consider this line sufficiently safe and commodious for all the purposes of the country; and the following is an estimate of their probable expense:

Improvement at Low-bridge - - - - - - - -	£. 1,100	-	-	Estimate of Improvements.
Improvement north of Lochy-Ferry - - - - - -	500	-	-	
Repairing road on south side of Loch Lochy - - - - -	600	-	-	
	£. 2,200	-	-	£. 2,200.

All the other roads in this division are valuable to the different districts through which they run, and require only to be kept in their present good condition.

4th.—SKYE DISTRICT.—*James Smith*, Inspector.

Description and Names of Roads.			Length in Miles.	Rate per Mile. £.	s.	d.	Annual Expense. £.	s.	d.
Parliamentary Roads	Ardelve & Lochalsh Roads -		16½	4	15	–	78	7	6
	Glenelg Road - - -		12	4	16	–	57	12	–
	Glenshiel Road - - -		16½	4	16	–	79	4	–
	Kintail Road - - -		10	4	16	–	48	–	–
Isle of Skye Roads	Macleod's Road -	117	19	4	10	–	85	10	–
	Skye Roads - -		73½	4	15	–	349	2	6
	Snizort Road - -		25	4	10	–	112	10	–
			172½				810	6	–

The roads in this district are all in perfect order, and having been recently made, no alteration or additional improvement is required on them.

5th.—ROSS-SHIRE DISTRICT.—*Robert Murray*, Inspector.

Description and Names of Roads.		Length in Miles.	Rate per Mile.	Annual Expense.
			£. s. d.	£. s. d.
Parliamentary Roads	Beauley Road - - -	15 ½	12 - -	186 - -
	Contin Road - - -	7	10 - -	70 - -
	Fearn Road - - -	23 ½	7 10 -	176 5 -
	Fortrose Road - - -	14	8 - -	112 - -
	Kessock Branch Roads -	8	6 - -	48 - -
	Kishorn Road - - -	15	3 5 -	48 15 -
	Loch-Carron Road, Sect. 1st	33 ½	5 - -	165 5 -
	Ditto - ditto - Sect. 2d	16	4 - -	64 - -
	Strathglass Road - -	23 ½	5 - -	117 10 -
	Tain Road - - -	15	6 6 -	94 10 -
Military Road -	Fort-George Road - -	13 ½	11 8 5½	151 16 11
Ross-shire County Roads.	Invergordon Road - -	18 ½	7 7 -	135 19 6
	Dingwall Road - - -	6 ¾	8 - -	54 - -
		209 ½		1,424 1 5

The roads in this district are very important, forming two great lines of communication, with some cross branches; the first, extending along the east coast from Inverness, by Beauley, Dingwall and Tain, to Bonar bridge; the second, extending across the county from Dingwall, by Contin, to Loch-Carron, Skye and Shieldaig on the west coast; and the others intersecting the peninsula, called The Black Isle, with a branch up the valley of Strathglass, and a cross-branch to Bonar bridge, from Novar.

There are very few improvements necessary on these roads; some, however, would be of advantage on that between Dingwall and Tain, the greater portion having only been renovated in surface by the Commissioners; and as it is now a toll-gate road, those improvements may be more speedily carried into effect.

On leaving the main street of Dingwall, the road runs through a narrow and inconvenient passage by the church to the canal, making two awkward bends at right angles, in the short space of about three hundred yards. These inconveniences may be entirely avoided by a very short variation; and it is understood that Mr. Davidson, of Tulloch, the present Member of Parliament for the County of Cromarty, has, with much public spirit, purchased the property through which it would pass, solely for the purpose of appropriating it to this desirable improvement, which will form a handsome entrance to the town on that side.

Fort George Road.

In this district is also included the Fort-George military road, extending from Inverness to the fortress of that name. This line, as forming the northern portion of the great

post-road from Aberdeen to Inverness, has been often the subject of complaint, both on account of its awkward direction, and occasional deficiency in breadth, being in some parts not more than ten feet wide; and the county, at length impressed with the necessity of altering and improving it, have caused a survey to be made lately, with the view of applying to Parliament for a Turnpike Act in the ensuing session. Should the projected improvements be carried into effect, a saving in distance to Nairn of two miles would be obtained, and all the inconveniences of the old line avoided.

6th.—CAITHNESS and SUTHERLAND DISTRICT.—*Thomas Spence*, Inspector.

Description and Names of Roads.		Length in Miles.	Rate per Mile.	Annual Expense.
			£. s. d.	£. s. d.
Parliamentary Roads	Dunbeath Road - -	33	11 9 6½	378 15 –
	Dunrobin, or Coast Road	47	9 9 9	445 18 –
	Thurso Road - - -	20	9 5 4	194 12 6
	Tongue Road - -	49½	5 5 –	258 12 6
		149½		1,277 18 –

This district consists of two main lines of road; one being the continuation of the Great North road from Bonar Bridge, by Golspie and Berriedale, to Wick and Thurso; the other stretching through the interior of Sutherland to Tongue.

On the former of these, between Brora and Dunbeath, various alterations may be made with advantage, which the increased traffic occasioned by the fisheries and the rapid agricultural improvement of this country, as well as its general importance as being the great mail line of communication, now demand; and justify an additional expenditure to that originally considered sufficient. The principal defects consist in a succession of awkward bends at different ravines, formed originally with a view to avoid the expense of large bridges and embankments; but which are found to be great obstacles to the rapidity of travelling, rendered necessary from the increased intercourse that now exists on these roads; but the most dangerous part of this line is in the ascent and descent at Berriedale, where the inclinations vary from one in eight to one in twelve and fourteen. This can only be obviated by expensive deviations from the present direction, which, however, for the reasons stated above, appear to be necessary. Dunrobin Road.

The Tongue Road, extending from Bonar Bridge to the seat of Lord Rae at Tongue, is a valuable communication between the east and north-west coasts, and has lately been improved by constructing parapets, and widening it at the expense of the local trustees of the county; it is now in perfect order, and suitable in every respect for the purposes of the country. Tongue Road.

By the public-spirited exertions of the Marquis of Stafford, the county of Sutherland has been intersected with numerous cross roads, highly beneficial to the different districts

through which they run. There is one, however, which seems to be of more public importance than any of the others, extending from the termination of the Parliamentary line at Tongue to Thurso, which still requires to be completed. Indeed it is only necessary to glance at the map to perceive the value of this line, both as connecting these two points, and as supplying a commodious access for the inhabitants along that coast to the town of Thurso, the principal mart of the country. Thirty miles of it have already been made, viz. through the county of Caithness and the estate of Sutherland; but the execution of the remainder, from the Kirk of Farr to Tongue, through the estate of Lord Rae, being a distance of ten or twelve miles, appears to be put aside for want of sufficient means on the part of the Trustees to carry it into effect. In the event however of its being ultimately resolved upon, it is proper to state that some improvements would also be necessary on the portion already formed, to complete the accommodation, particularly in the construction of two bridges of considerable size.

Road from Tongue to Thurso.

The above detail comprehends what seems necessary for rendering the various roads under charge of the Parliamentary Commission perfect, as far as regards local communication and safety of travelling. Your Lordship has witnessed the effectual manner in which every obstacle to the improvement of the Highlands, arising from their hitherto inaccessible situation, has already been removed by the active and judiciously directed measures of the Commissioners; and the face of the country generally, as contrasted with its condition before the commencement of their operations, exhibits every where the appearance of industry and increasing opulence, which are the necessary consequences of facilitating the intercourse between its several parts. Numerous valleys of very considerable fertility, as well as extensive ranges of sea-coast, where formerly cultivation (even if it had not been entirely neglected) would have been comparatively useless, from the difficulty of conveying its produce to market, are now little behind the southern parts of the kingdom in the advancement of agricultural and commercial industry; the fisheries, although at some stations less successful than originally anticipated, have been essentially promoted by rendering more perfect the communication between their different establishments, and connecting them with the low country and opposite coasts; and, in general, outlets have been provided for the various commodities which the country supplies.

These advantages are sufficiently apparent in the improved habits and increased comforts which are gradually gaining ground among the inhabitants of the Highlands, and which are not only intimately connected with the advancing state of the country, but may, in a great measure, be ascribed to the immediate influence of those public works which have given the first impulse to its improvement, and the execution of which necessarily supplied with employment no inconsiderable portion of its population. These furnish the best comment on the measures of the Commissioners, and afford the amplest justification for the aid which Government, in so liberal and enlightened a spirit, granted towards the progress of their undertakings; while the increased sources of revenue, which must obviously result from such a state of things, promise eventually to repay not only what has already been expended, but what may still be afforded towards the furtherance of the same objects.

Before quitting the subject of roads, permit me to add a few short remarks on matters which have recently been under discussion, and with which the future utility and condition of the Highland roads are intimately connected. Remarks.

Some years have now elapsed since the proposal for substituting tolls in lieu of the county assessment for the repair of these roads was brought forward, and as in those instances in which it has already been acted upon there seems every prospect that the objects it had in view may be finally accomplished, little room is left to doubt of its general expediency. Indeed all must concur in the propriety of relieving the heritors, who have hitherto acted so liberally in furthering the measures of the Commissioners, to any extent that will not be burdensome to the public. A statement is annexed, showing the amount of tolls collected within the last two years on roads in charge of the Parliamentary Commissioners in the Highland counties of Caithness, Ross and Inverness. Tolls on Highland Roads.

From this, however, has arisen another proposition, with respect to which no such unanimity prevails; namely, that for making over certain of the roads now under the charge of the Parliamentary Commissioners to the management of the local trustees. This is a matter that requires mature consideration before any decisive steps are adopted that may ultimately more or less affect the utility of those roads which have hitherto been found to act so beneficially under the paternal care of the Commissioners. The confidence which the public have ever been disposed to repose in their operations might not be so easily transferred to bodies of individuals, warped by various and contending interests and prejudices, which, in county matters, are but too often found to interfere materially with the discharge of public duties. The Commissioners, while their jurisdiction extends over all the roads in the Highlands, will, it is natural to suppose, only promote the views of particular districts as they are likely to advance the general interests of the whole; but it cannot be expected that trustees only concerned in their own immediate county or neighbourhood would have the same liberal and extensive views. Proposal for making over some of the Highland Roads to local Trustees.

The inconvenience likely to arise from this change might, indeed, in a great measure be avoided, by reserving in the hands of the Commissioners the exercise of a general control over the operations of the trustees, who might thus relieve the Commissioners from a considerable burden in the management of the details, while the responsibility attached to their proceedings would secure the expenditure of the tolls collected on the roads in a prudent and skilful manner. It were well, however, that even this arrangement should not be conceded until the roads are finally completed and placed in a perfect condition; and that it should in general be confined to communications that are more strictly of a local description, which might with great safety be entrusted to the care of those for whose special advantage and on whose representation they were originally constructed; the Commissioners retaining the entire management of the great lines of communication, which, on no consideration, ought to be left to the risk of having their general utility, and even safety, endangered, by probable neglect of any of the several trusts.

BRIDGES.

On all the roads under the charge of the Commissioners, the bridges which have hitherto been constructed are at present in good condition, being frequently inspected, and regularly pointed and repaired where necessary.

Bonar Bridge. The foundations of the piers of Bonar bridge (which is the only instance where they have been laid in caissons) are occasionally examined at spring ebbs, and carefully protected with quarried rubble-stones whenever it appears to be required. As your Lordship has observed, the wing-walls on the north side of this bridge are too low, and the approaches require to be further protected with parapet walls; but these defects are already provided for in the contract lately entered into for the repair of the Sutherland coast road.

In this department, sufficient provision does not seem to have been made for the occasional decay, or accidental destruction of the large bridges by sudden floods, and the consequence has been that the bridge of Laggan-kirk, and the timber bridge over the Tarff at Fort Augustus, which were both swept away, have for a considerable period lain in ruins, to the great inconvenience of the districts in which they are placed. The county of Inverness, however, with their usual liberality, agreed at their last April meeting to assess themselves in half the expense of rebuilding not only the two bridges just mentioned, but also that across the Oich at Aberchalder, the execution of which had been delayed until the position of the canal bridge was fixed on; and as I understand the Commissioners (in whose hands estimates have been lodged) have consented to pay the other half, I believe the only impediment to the immediate erection of these bridges is a difference of opinion as to the comparative propriety of timber and iron bridges for their respective situations.

Aberchalder Bridge.

PIERS, HARBOURS, &c.

None of the harbours are strictly under the charge of the Commissioners at present, it having been considered that, from the powers granted by the Act, the persons to whom they were important would be able to levy dues sufficient for their preservation and repair. In no case, however, have these been imposed, except at the harbour of Portmaholmack, and here the regulations have only been finally put in force during the last year.

Portmaholmack Harbour. Since the completion of this harbour, up to January last, no attention had been paid to it, and it consequently required renovation in some parts of the masonry, and clearing away of mud which had accumulated within its return head. On this being done, at the expense of Messrs. Macleod of Cadboll and Geanies, the principal proprietors in the neighbourhood, the Commissioners granted them powers to appoint a collector, and levy dues regularly; and I have inserted a statement of their produce, from the 6th of July to the end of the past year, which proves that the revenue derived from this useful work is adequate to maintain it in proper repair. (£.28. 15*s.* 2*d.* in half-year ending December 1827.)

Ballintraed Pier. The pier of Ballintraed, in the Dingwall Firth, has been of great service to the neighbouring country, being the only place also by which the trade from Tain, and the surrounding district, to Leith and Aberdeen, is carried on. No dues have been yet levied on the vessels using it. An accumulation of mud has been suffered to take place of late; but the proprietor is desirous of having this pier put on the same footing as the harbour at Portmaholmack, in order that the sums collected may be applied to effect the necessary repairs.

At the head of the same firth, the Dingwall Canal was executed with a view to the accommodation of that town, and the rich and fertile country which surrounds it; and it has been of great service in promoting the trade in that quarter. It has, however, either from mismanagement or actual deficiency in the necessary funds, been allowed of late to fill up with sand and silt to such a degree, that the navigation has been rendered, in a great measure, useless; and vessels of large burthen are now under the necessity of discharging their cargoes, as formerly, on the adjacent beach. This inconvenience might, I am of opinion, be entirely obviated by the construction of floodgates at its entrance, and near the lower basin; but more minute investigation would be necessary to ascertain how far the foundations would be suitable, and whether it might not possibly be kept clear by less expensive means. Dingwall Canal.

From a statement, shewing the number of vessels that have navigated it for the last three years with the amount of their tonnage, furnished me by the town clerk of Dingwall, it appears that the magistrates are very desirous that the Commissioners should assume the management of it; but it does not appear that the town proposes to provide any funds for the necessary improvements. (184 vessels, 7,276 tons, in three years.)

The shipping-piers at the burgh-town of Fortrose and village of Avoch have fully suited the objects for which they were built, and have hitherto remained in tolerably perfect order; but it were well that toll-dues, as authorized by the Act, were also established at these places, to meet the expense of any casual repair. Fortrose and Avoch.

The ferry-piers on the west coast, at Crinan and Kiels, at St. Katharine's, Lochie, Kyle-haken, Kyle-rhea, Strome and Dornie, which are deemed to be part of the roads to which they respectively belong, are all occasionally inspected and kept in good repair, and render the passage at each of those ferries safe and commodious. Ferry Piers.

The piers at Corran Ferry are of more defective formation, which can only be attributed to the inferiority of the materials of which they were necessarily constructed, there being none of a better quality in the neighbourhood. The repairs, however, when necessary, are punctually attended to, in like manner as other road-repairs, to which class they belong. Corran Ferry.

FURTHER NOTICES of the Improved State of the Highlands of Scotland.

In March 1799, Col. Anstruther, superintendent of the military roads in the Highlands of Scotland, in a memorial to the Lords of the Treasury relative to these roads, states, that 'they passed through the wildest and most mountainous parts of the Highlands 'of Scotland, where the people were poor and the country thinly inhabited, and totally 'unable to keep in repair either the roads or bridges by statute labour, or any other 'means.' The district to which this observation referred was situated more immediately in contact with the low countries, the military roads extending no farther northwards than the Murray Firth and the fortresses along the Caledonian Glen and the wide and extensive country beyond, comprising the counties of Ross, Cromarty, Sutherland and Caithness, with the greater part of Inverness-shire and the whole of the western islands, intersected as it was by arms of the sea, dangerous ferries, deep and rapid rivers, and

innumerable lesser streams, subject to frequent and sudden floods, without the accommodation of bridges, piers or other facilities, was, as may be conceived, in a much worse condition. The internal communication was attended with the utmost difficulty and danger, and any considerable intercourse with the low countries was rendered almost impracticable; which was, no doubt, the principal cause that the Highlands, thus insulated, remained in their unimproved condition, while the southern parts of the kingdom were in all directions making rapid advances in every species of industry and civilization; and to such a degree did the want of safe and easy intercourse between the northern counties affect even the ordinary administration of justice, that until of late years the counties of Sutherland and Caithness were not required to return jurors to the northern circuits at Inverness.

Such may, in a few words, be described as the state of the Highlands previous to the year 1803, when the Parliamentary Commissioners commenced their operations.

Since that period, the progress of these works has gradually laid open the most inaccessible parts of the country; and the Commissioners, by combining the efforts of all the counties in the prosecution of one great general measure of improvement, have succeeded in effecting a change in the state of the Highlands, perhaps unparalleled in the same space of time in the history of any country.

Travelling.

Before the commencement of the present century, no public coach, or other regular vehicle of conveyance, existed in the Highlands. In the year 1800, it was attempted to establish coaches between Inverness and Perth, and between Inverness and Aberdeen; but, from the state of the roads at that period, and the little intercourse which then took place, it was found necessary to discontinue them after a short trial; and it was not until 1806 and 1811 that coaches were regularly established in these directions, being the first that ran on roads in the Highlands.

Since the completion of the Parliamentary works, several others have successively commenced; and during the summer of last year no less than seven different stage coaches passed daily to and from Inverness, making forty-four coaches arriving at, and the same number departing from, that town in the course of every week. Three of these, including the mail, run between Inverness and Aberdeen; one between Inverness and Perth, along the Highland road; two between Inverness and Dingwall, Invergordon, Cromarty and Tain; and the mail coach along the northern coast road from Inverness to Wick and Thurso, extending from the capital of the empire, in one direct line, above 800 miles. This latter coach was not established until 1819, and much doubt was entertained at that time of its success. Indeed, some assistance was at first required from the counties to support it. This was, however, soon afterwards withdrawn, and the encouragement it has since met with has enabled the contractors to increase its original speed to eight miles an hour, and latterly to employ four horses for the first fifty miles north of Inverness, notwithstanding the opposition of the two other coaches above mentioned. There has also been established, within the last two years, a stage coach from Inverary to Oban in Argyleshire, over a considerable part of the improved military line in that district of the Highlands; and when it is stated that, in connection with

these coaches, more than 13,000 passengers went last year through the Crinan Canal, that three steam-boats plied regularly for the conveyance of passengers along the Caledonian Canal, and five others from Glasgow, along the west coast, and to the different islands of Skye, Mull, Islay, &c., as well as one occasionally from Leith, along the east coast, to Inverness, some idea may be formed of the increased intercourse that has taken place between the remotest parts of the Highlands and the southern counties within the last few years.

Inns.

It deserves notice also, that, along all the roads constructed by the Commissioners (extending in length upwards of 900 miles), excepting on the Laggan road, suitable inns, affording accommodation superior to what could be expected considering their recent introduction, have been erected or fitted up at regular stages; while formerly, even had other facilities existed, the total want of accommodation for travellers would of itself have presented a serious obstacle to all internal intercourse.

Post-chaises &c.

Post-chaises and other modes of travelling have, during the same period, increased proportionally; and instead of five post-chaises, which was the number kept in the town of Inverness about the year 1803, there are now upwards of a dozen, besides two establishments for the hire of gigs and riding horses, all of which find sufficient employment. Post-chaises and horses have also been kept, for the last two or three years, at all the inns on the great Highland road, and also at Dingwall and Tain, and at Inverary.

Private Carriages.

The number of private carriages in Inverness and its vicinity has likewise increased remarkably during the last twenty five years, and no less than one hundred and sixty coaches and gigs may now be seen attending the Inverness yearly races; whereas, at the commencement of that period the whole extent of the Highlands could scarcely produce a dozen; and at no very distant date previously, a four-wheeled carriage was an object of wonder and veneration to the inhabitants. In 1715, the first coach or chariot seen in Inverness is said to have been brought by the Earl of Seaforth. In 1760, the first post-chaise was brought to Inverness, and was for a considerable time the only four-wheeled carriage in the district. There are at present four manufactories for coaches in Inverness.

Carriers.

I may state also, that, on all the principal roads which have been constructed in the Highlands, regular carriers, for the conveyance of goods, now pass at all seasons of the year from Inverness to Tain, Skye, Loch-Carron, Loch-Alsh, Elgin, Nairn, Campbelltown, Aviemore, &c.; and others from Glasgow to Ballachulish, &c., in the western district.

Post Office.

Perhaps in no instance has the beneficial influence of the Parliamentary works been more perceptible in its result than in the speedy and certain conveyance of intelligence to the remotest quarters of the Highlands. Through their whole extent, this department is now conducted with as much regularity and despatch as in any part of the kingdom; and when I state that the following extract from a letter, which I have received from a gentleman in the island of Skye, is equally applicable to the other districts in which roads have been constructed, it will be unnecessary for me to add any thing further on

this part of the subject. 'The communication of our letters and newspapers by the 'mail is very different now to what it was about twenty years ago. Previous to the 'completion of the roads, we had first only one, and afterwards two mails a week; and 'these were only carried on runners' backs. There was only one runner from Inverness 'to Janetown; and there being no piers or landing places, or indeed regular ferry-boats, 'the detention at the ferries must have been occasionally very considerable. We are 'now very differently situated. We have a regular communication three times a week 'with Dingwall, with a change of horses at different stations to the ferry of Kyle-haken; 'and, as an instance of the facility of communication, I receive a London Sunday news-'paper regularly here (Portree) every Thursday morning; a circumstance which must 'appear to a stranger almost incredible, and which of course is solely attributable to the 'roads made under the authority of the Parliamentary Commissioners.'

District Roads. Not less remarkable, though more indirect, has been the impulse given to agricultural improvement throughout the Highlands. The construction of the Parliamentary roads having in the first instance opened the means of access through the districts generally, and also the intercourse with the low countries, a desire was naturally excited among the proprietors and tenantry, more or less remotely situated, to connect themselves immediately with the general lines of communication, and thus avail themselves of the facilities which they afforded for improvements in agriculture. Hence, numerous lines of district road have been constructed during the progress and since the completion of the Parliamentary works, in every part of the Highlands, by means of statute labour; and the rapid and important increase in the extent of cultivation, which has uniformly been the consequence, proves in a striking degree the favourable effects resulting from the works of the Commissioners. Their roads being executed without reference to any individual interest, they were made in lines most calculated for the general good, and necessarily pointed out the proper direction of those subsidiary branches which were required to be made by the statute labour and out of private funds. The public aid afforded for the Parliamentary works kept the local funds, in great measure, entire for such separate purposes; and the knowledge gained from observing the works of the Commissioners saved much expense, and furnished the assistance of skilful engineers and experienced workmen.

Upon this subject I have received the following communication from good authority: 'In illustration of the spirit which these public works have excited, and the incalculable 'benefits which they have produced already, and may produce more extensively hereafter, 'it may be sufficient to refer to the recent Act for regulating the statute labour of the 'county of Sutherland, by which the services in kind were converted into a money 'payment. The county having been divided by this Act into four districts, in the first of 'them, the Dornoch district, nineteen miles of new road have been made with requisite 'bridges, by the joint means of composition for statute labour and contribution from 'Lord Stafford, the principal proprietor; in the second, or Sutherland district, seventy-'five miles of road have been made by the like means, besides a line of twenty-five miles 'from Torgue down Strathnahaver to Altnaharrow, and a direct line of thirty-seven miles 'from Helmsdale on the east coast to Bighouse on the north coast, both of which have

'been effected by statute labour funds exclusively; in the third, or Reay district, there 'is now constructing a road of thirty-four miles from Altnaharrow to Durness; and in 'the fourth, or Assynt district, several roads and bridges also have been constructed, and 'one line of forty-four miles in length from the east coast up Strath-Orhil to Loch Inver 'on the west coast, intersecting this portion of the island at right angles to the Helms-'dale road; this important line has been made partly by the statute labour funds, partly 'at Lord Stafford's expense, and four miles of it entirely by the late Lord Ashburton.

'One immediate result of making these roads has been the substitution of carts instead 'of ponies for the commercial intercourse of the country; and the saving in point of 'time, and labour and expense in this respect is beyond all calculation, giving a new 'impulse to the improvement of the country. The people are extending their smaller 'roads in all directions for their carts to bring sea-weed from the shore, or their fuel from 'the peat mosses; and activity, energy and industry have taken place of their former 'indolence, sloth and idleness; raising every where more comfortable and better-built 'cottages, with the addition of gardens, an accommodation and source of supply to such 'heretofore unknown, but now getting into very general use.'

Agriculture.

With regard to the state of husbandry, the following extract from the letter before mentioned will suffice, as applying with equal, and in many cases with greater, force to all parts of the Highlands:—'With the exception of a few carts, which were in the 'possession of a very few individual principal tenants, paying a rent of from £. 200 to '£. 700 a year, there were none to be found in the Island of Skye. There are now 'numerous carts in every quarter; and their introduction has in like manner been the 'means of introducing other useful implements, such as the plough and iron-teethed 'harrows; neither of which were much used, excepting by the principal tenants, not 'many years ago. These improvements have, without doubt, been caused solely by the 'roads made under the authority of the Parliamentary Commissioners, as without roads 'there could of course be no carts; and although it may be true that, by having roads 'made on different farms, certain advantages might have been derived, still, as these 'roads would be merely local, no great general good could be derived from them, as 'they could not possibly open up the communication from one place to another.'

At the commencement of the present century, from the difficulty of conveyance for exportation, cultivation was almost entirely confined to narrow strips of land situated along the sea coast, and in the immediate neighbourhood of the few sea-port towns; and even here was not brought to that state of perfection which, since the introduction of implements of a less defective description than those formerly used, it has of late years attained. As an instance of the improvement that has taken place in Ross-shire, now the most beautiful and highly cultivated county in the Highlands, I may mention, that there is at present in the service of Major Gilchrist of Ospisdale, in Sutherland, as farm manager, the individual who first introduced the ploughing of land into regular ridges and the division of fields into any thing like systematic arrangement in that county; the fields being formerly detached pieces of land, ploughed irregularly, as the ground, with the least labour, suited. The carts generally used were of the poorest description, with a kind of tumbler or solid wheel, and wicker conical baskets; little or no lime was

used for agricultural purposes. 'I succeeded to a farm in this country about thirty 'years ago (says Major Gilchrist), when the working strength consisted of sixteen oxen 'and twenty-four small horses called garrons; this farm is now laboured by three pair 'of horses.'

The total amount of wheat then raised in the county was not equal to what is now produced on many single farms. It was not until 1813 that the first barley-mill north of the Cromarty Firth, was erected, and in 1821 the first flour-mill (at Drummond on the estate of Fowles) by the same individual. To such an extent, however, has cultivation of late years been carried, that the growth of wheat alone is now estimated at twenty thousand quarters annually, and the exportation of grain to London, Leith, Liverpool, &c., during the last year, amounted to upwards of ten thousand quarters; besides the supply of the extensive and populous pastoral districts of the county, and the towns of Dingwall, Tain, Inverness, &c., to which places, I am credibly informed, upwards of ten thousand bolls of flour are now annually sent for the consumption of the inhabitants. Among other exports may likewise be mentioned, the produce of various extensive whisky distilleries situated in different parts of the county, and a considerable quantity of salted pork, bacon, &c., from the ports of Cromarty and Invergordon. I understand that, in the year 1819, the sum estimated to have been expended in the purchase of the latter commodity amounted to about £. 30,000. Indeed, a marked improvement in domestic animals of every description has taken place in the northern counties since the improved communication with the south. I need hardly allude to the introduction of Cheviot sheep, to the pains taken in improving the breed of cattle by the importation of the most improved sorts from the West Highlands, and of cows from Ayrshire. Considerable attention has been recently paid to the breed of horses, both for the purposes of agriculture and draught, and in some instances those of the finest description have been successfully reared. Nor has the breed of pigs been neglected, several valuable species, both pure and crosses, having been introduced. In short, a general spirit of approximating these counties, in as far as the soil and climate will permit, to the more advanced counties in the south, seems every where to prevail.

The improvements in many parts of Inverness-shire have been scarcely upon a less extensive scale than in the county of Ross, although the field for agricultural operations in that county is naturally more limited.

In the county of Sutherland, the objects of the Commissioners have been promoted in an extraordinary degree, by the liberal exertions of the Marquis of Stafford, and other heritors, who have effected a complete revolution in the state of that extensive district of the Highlands. Agriculture is there conducted on the most approved plans, and farm buildings, and other establishments of husbandry, have been erected on a scale equally extensive and complete as in the most improved parts of the kingdom. This is the more remarkable, as not twenty years ago nothing of the kind existed; and until that period, the great body of the inhabitants were confined to the upper parts of the country, and had undergone little change from their primitive and uncultivated habits, living in huts of the most wretched description, and strangers to every species of industry or comfort.

Latterly, however, crofts or small portions of ground were gradually lotted out for them near the coast, in such positions as were best calculated to employ their labour with advantage to themselves and to the country; and every encouragement was given for the improvement of the lands, and the erection of comfortable and suitable cottages; while the upper parts were converted into extensive farms for the rearing of cattle and sheep, to which they are naturally adapted, and in which way only they can prove valuable to the proprietors or to the community. That the first impulse to these important changes has been given by the operations of the Commissioners is no more than is uniformly acknowledged in the statements of those individuals under whose directions the improvements have been conducted.

In confirmation of these remarks, I have received a letter from a gentleman residing in Sutherland, from which the following is an extract:—'When I came to the Highlands 'in 1809, the whole of Sutherland and Caithness was nearly destitute of roads. This 'county imported corn and meal in return for the small value of Highland kyloes (cattle), 'which formed its almost sole export. The people lay scattered in inaccessible straths 'and spots among the mountains, where they lived in family with their pigs and kyloes, in 'turf cabins of the most miserable description; spoke only Gaelic; and spent the whole 'of their time in indolence and sloth. Thus they had gone on from father to son, with 'little change except what the introduction of illicit distillation had wrought (and this 'evil was then chiefly confined to the vicinity of Caithness); and making little or no ex-'port from the country beyond the few lean kyloes, which paid the rent, and produced 'wherewithal to pay for the oatmeal imported. But about this time the country was 'begun to be opened up by the Parliamentary roads,—by one road, from Novar to Tongue, 'through the barren mountains of which that district is composed, and by another, pass-'ing along the east shore towards Wick. Certainly, a more striking example of what 'roads do effect,—and effect too in an extremely poor country,—has rarely been seen; 'such a quick exhibition of what natural wealth lay latent in such a country is unexam-'pled. Your roads were opened, when the agricultural distresses were just beginning. 'In the face of that distress we now annually export from the barren district about 80,000 'fleeces of wool, and 20,000 Cheviot sheep; and from the sea-coast several cargoes of 'grain, the produce of three considerable distilleries of Highland whisky, a good many 'droves of well-fed cattle, and from 30,000 to 40,000 barrels of herrings, besides cod, 'ling, &c. But the most happy result, in my opinion, is its effect upon the people. The 'fathers of the present generation of young men were a great many of them brought by 'compulsion to the coast; others, after they came to substitute carts and wheels for their 'former rude contrivances, have drawn down to the road-side of themselves. The effects 'of society upon human nature exhibit themselves;—the pigs and cattle are treated to a 'separate table; the dunghill is turned to the outside of the house; the Tartan tatters 'have given place to the produce of Huddersfield and Manchester, Glasgow and Paisley; 'the Gaelic to the English; and few young persons are to be found who cannot both read 'and write.'

Another well-informed correspondent writes to me thus:—

'About the year 1809, the fifty miles of country between Sutherland and Inverness 'was first begun to be laid open by roads to the south. There was till then no regularly

'formed road in that part of the country,—no harbour, no attempt to drain the land,—'turnips and wheat were little known; and when Lord Stafford and his tenants originally 'began their improvements, a well-constructed plough had never been seen in Sutherland, 'and the inhabitants were entirely unacquainted with using ploughs in a workmanlike 'manner. At that time nothing could have led me to believe that, in the short space of 'ten years, I should, in such a country, see roads made in every direction, the mail-coach 'daily driving through it, new harbours constructed, in one of which upwards of twenty 'vessels have been repeatedly seen at one time taking in cargoes for exportation; coal, 'and salt and lime, and brick-works established; farm-steadings every where built; fields 'laid off, and substantially inclosed; capital horses employed, with south-country imple-'ments of husbandry made in Sutherland; tilling the ground, *secundum artem*, for turnips, 'wheat and artificial grasses; an export of fish, wool and mutton, to the extent of '£.70,000 a year; and a baker, a carpenter, a blacksmith, mason, shoemaker, &c., to be 'had as readily, and nearly as cheap too, as in other countries.'

The same correspondent informs me—that

'When the line of road from the Fleet Mound to the Ord of Caithness was commenced, 'the object of every one was to get it carried as far from their door and arable lands as 'possible. It was carried therefore, generally speaking, at the outside of the cultivated 'district, at the base of the mountains. Bitterly do the present possessors lament the 'blindness of their predecessors. The effect, however, has been extremely advantageous 'to the country; it has forced the occupiers to cultivate carefully all the uncultivated 'corners of their arable land below the road; and this line has served as a new base to 'start from for the cultivation of all that lies above it, and that is fit for the plough. The 'old track which communicated with Caithness lay along the beach, close by the sea. But 'being since carried into the interior, the consequences have been, a village built at Bonar 'Bridge, a great tract of country planted by Messrs. Houston of Creech, and Dempster of 'Skibo; the whole of the arable part of the Creech estate subdivided with the best in-'closures, trenched to a great extent, and all under the best system of modern husbandry; 'a distillery erected, and a new farm torn from the mountain's side at Skibo.

'The effects produced by the Parliamentary roads in Caithness I can from experience 'state to have been very great, having had to ride into it, the first time I knew it, in '1813, and having visited it in 1826 in a carriage. About Wick the additional cultivation 'is very great, and all along the road-side considerable symptoms of improvement are 'every where seen; the same is still more conspicuous, I understand, from Wick to Thurso. 'They are making a shorter road to the latter place, called the Kerseymire road, which 'will bisect the county; but though Caithness is capable of vast agricultural improve-'ment, yet that must necessarily be slow, as many of the lands are fettered most strictly 'by their entails.'

I have not been able to acquire more specific information regarding the county of Caithness; but it is only necessary to contrast the state of the districts immediately bordering on the Parliamentary roads passing through it, with that of the more unconnected portions, to perceive the important effects that have attended them; and as this county is naturally more susceptible of agricultural improvement than any of the others, the most

beneficial consequences may reasonably be expected from still further opening the interior by additional roads. As an instance of the present condition of some parts of this county along the Parliamentary roads, I need only mention that one farmer, in the year 1826, exported grain, the produce of his own farm, to the value of not less than £. 2,000. Indeed I may state generally, as equally applicable to the whole of the Highlands, that in my various journeys to the different parts of the country, I notice improvements extending in every direction; and during my short recollection, a considerable extent of moor-land in various places has been inclosed and converted into cultivated fields. It may also serve to shew how systematic farming has become, that societies for the promotion of agriculture and the rearing of stock have been established in all the northern counties.

Nor have plantations been behind in this general state of improvement. Many thousands of acres have within the last twenty-five years been planted; upon the Dunrobin estate alone, there have been planted within the last twenty-five years above nine millions of trees; and although the climate is somewhat unfavourable for the growth of large trees, yet the attempts made promise to be attended with profit and advantage in many situations incapable of any other species of culture. Plantations.

The rapid improvements in agriculture have been accompanied with a corresponding change in the habitations of all ranks in the Highlands. Proprietors have expended large sums in the erection and ornamenting of suitable mansion-houses; and in the houses of gentlemen-tacksmen every species of comfort and convenience is to be found; while the cotters are gradually exchanging their huts of mud or turf for neat and substantial cottages. To aid this beneficial change in the circumstances of the latter, great encouragement has in various instances been given by the heritors in granting timber, windows, lime, &c.; and I am enabled to state that, in the Island of Skye alone, no less a sum than £. 100,000 has been expended by the late Lord Macdonald, in the erection of buildings and other improvements. I may here also mention a fact, from which the general state of the Highlands, before the Parliamentary works were undertaken, may be inferred; namely, that at the period of his Lordship's accession, in 1797, to his estates in that Island, comprising nearly five parishes, there were throughout their whole extent no churches, only one manse, two or three small slated houses, and only one slated inn. Houses.

To this Island, and to the other Islands and Highlands of Scotland, by a recent Act of Parliament, passed in the reign of his present Majesty, the benefit of additional places of worship has been extended; and substantial churches, with suitable manses, have been erected in more than forty places, where none existed four years ago, from Isla and Iona to the Orkneys and Shetland. Churches.

It will naturally be inferred, that a great increase in the value of property must have arisen from the foregoing circumstances; and a few facts will serve to place the change that has here been effected in its strongest light. In Inverness and its vicinity, the increase has been in several instances nearly tenfold; for instance, the lands of Merkinch, situated between the town and the canal, rented twenty-five years ago between £. 70 and £. 80, while the rental for the last year amounted to £. 600. In 1790, the property of Redcastle, on the opposite shore of the Beauley Firth, was sold for £. 25,000, and in Property.

1824, was again sold to Sir William Fettes, Bart. for £.135,000. Nor has the change been less striking in the districts of the Highlands more removed from the influence of the northern capital. It is sufficient to refer to what has been done by capitalists from the Lothians and Northumberland on the Stafford estates in Sutherland. The beneficial influence of the operations in that quarter has also been felt through the most inaccessible parts of Lord Reay's country, where inclosures have been made, farm-houses erected, and the rental largely increased. The estates of Chisholm, situated in the romantic district of Strathglass, have risen since 1785 from £.700 to be now upwards of £.5,000 per annum. When D^d. Macdonald, of Glengarry, died in 1788, his yearly income did not exceed £.800; the same lands now yield from £.6,000 to £.7,000 a year.

I have little doubt that a corresponding increase has taken place in most parts of the Highlands, but the present is a very unfavourable period for bringing forward instances, particularly in the pastoral districts, owing to the depreciation in the price of wool, sheep, cattle, &c., which has in a peculiar degree affected the value of property in this part of the kingdom. This may well be inferred from the fact, that wool, which a few years ago was sold at from thirty-five shillings to two guineas per stone, produced at the last Inverness wool-market no more than twelve or thirteen shillings.

Trade. There cannot be a doubt but the increased facilities of communication, as leading to increased comforts, has naturally brought to market a greater variety and to a larger amount of produce and manufacture than was heretofore customary in the Highlands. Formerly Inverness supplied with foreign commodities almost all the Highlands, including Tain, Dingwall, Sutherland and part of Caithness. Since, however, the means of communication with the south have been more extended, and suitable harbours erected at other places, the supply to the several districts has been direct; and packets have been established from London and Leith to Wick, Thurso, Helmsdale, Brora, the Little Ferry, Tain, Dingwall, Invergordon, &c. Yet, notwithstanding this division, the trade of Inverness has increased very considerably since the commencement of the present century. About twenty-five years ago, there were only four vessels, averaging ninety-six tons, that sailed once in every six weeks between London and Inverness; there are now five vessels of one hundred and thirty tons, which sail every ten days. Since the opening of the Caledonian Canal, also, three regular traders from Liverpool have been established, besides a steam-boat for goods from Glasgow. In the Leith trade, only three vessels existed twenty-five years ago; there are now six regularly employed, and sailing twice every week. Thirty years ago, there was only one vessel of forty tons trading between Inverness and Aberdeen; there are now four, of sixty or seventy tons each. These vessels are principally employed in the importation of foreign commodities and manufactures; but the increase of general trade will best be seen by comparing the present amount of shore-dues with that in the year 1802. At that time, they produced only £.140 annually; while, in 1816, with some advance in the rates for the improvement of the harbour, they amounted to £.680. In 1817, the lower part of the canal was opened; and from the accommodation afforded in its basin, part of the trade was carried on there, which reduced the rates, in 1820, to £.470. Since that period, however, the annual rent has again risen to £.560.

The increasing wants of the inhabitants of Inverness sufficiently prove their increasing wealth; and since their closer connection with the southern counties, a rapid change has taken place in the general state of society. The manufacture of hempen and woollen cloths has been commenced; churches and chapels of various sects built; missionary and Bible societies established; schools endowed; an infirmary erected; reading-rooms established; subscription libraries set on foot; two newspapers published weekly; and a horticultural, a literary and various other professional and philanthropical institutions founded. Two additional banks have likewise been instituted, three iron-foundries, and three rope and sail manufactories have successively commenced; an additional bridge has been constructed; the harbour has been enlarged and improved; the town lighted with gas; and all within the last twenty-five or thirty years. But in no instance is the benefit arising from facility of communication more apparent than in the establishment (in 1817) of the great annual sheep and wool-market at this central point of the Highlands, to which all the sheep-farmers resort from the remotest parts of the country, to meet the wool-dealers and manufacturers of the south. Here the whole fleeces and sheep of the north of Scotland are generally sold, or contracted for in the way of consignment; and, in 1818, upwards of one hundred thousand stones of wool and one hundred and fifty thousand sheep were sold at very advanced prices. This circumstance affords a striking proof of the advantage of lines of communication in facilitating the exportation and sale of the staple commodities of the country.

It will not be unimportant to remark here, that banking offices have likewise been of late years established at Thurso, Wick, Golspie; two at Tain, and one at Fort William and at Inverary. Banks.

The foregoing observations, it will be understood, apply more particularly to those districts which have been opened and accommodated by the various works of the Commissioners; and although their influence has, in some degree, been felt through the whole extent of the Highlands, yet I have already explained how desirable and necessary various improvements, yet unaccomplished, are for the still further melioration of this extensive country.

Jos. Mitchell.

APPENDIX (L. 12.)

REPORT of the PARLIAMENTARY COMMITTEE to whom the REPORT, PLAN and ESTIMATE of a Road from *Carlisle* to *Glasgow*, made in the Years 1814 and 1815, were referred.

YOUR Committee have thought it advisable to pursue their inquiry under the three following divisions:

1. The present state of the road from Carlisle to Glasgow.
2. The advantage to be derived from a good road being made.
3. The merits of the proposed plan, and probability of its being carried into effect.

Your Committee have proceeded to hear evidence upon each of these points, and find on the first, that the present road is in a most defective and ruinous state, so much so as frequently to retard the mail and endanger the lives of passengers.

Indeed, one instance has been stated in evidence to your Committee, of an accident, owing to the decayed and ruinous situation of one of the bridges (viz. that over Evan Water), by which 'the mail coach and horses fell into the river, one passenger was killed 'on the spot, the coachman only survived a few days, and several other persons were 'dreadfully maimed; two of the horses were also killed.'

And although this accident happened several years ago, the bridge remains at this day in the same situation, except that the immense gulf made by one-half of the bridge falling, is fenced off by slight railing, and the mail and other carriages are now under the necessity of passing over the remaining half, which is just wide enough to admit a single carriage.

The state of this bridge as here represented, and indeed the general bad state of the road, is consistent with the personal knowledge of several members of your Committee.

In addition to the evidence of such persons as were acquainted with the road, by travelling on it, your Committee thought proper to examine Mr. Hasker, from the Post Office, who fully confirms and corroborates the other testimony, as to its defective and dangerous state; and has supplied your Committee with the following extract from the Glasgow time bill of the 23d of this very month, 'That five minutes are lost every journey, by the broken 'bridge over Evan being so much damaged, that there is hardly the breadth of the coach 'left standing.'

Your Committee find from Mr. Hasker, that numerous representations have been made to the Post Office, of the insufficiency of the road, and of the delay and even danger incurred by the mail during every winter, in its passage from Carlisle to Glasgow. Indeed it appears that this road has been, latterly, so very bad as to occasion doubts whether the mail would continue to convey the letters by it. Your Committee find, too, that remonstrances with the trustees and local proprietors of land have been often made, but in vain; and it appears to your Committee, that the advantages of this road are more of a general than a particular nature, and therefore not likely to engage the landed proprietors adjoining its course in any zealous efforts or expensive measures for its improvement.

Your Committee find, further, that the tolls have been raised as high as they can be raised, with any prospect of increasing the funds for maintaining the road; that these funds are not only exhausted, but the road very considerably in debt to proprietors, who have advanced money for its repair, and who have no prospect of receiving either principal or interest.

Your Committee think it would be superfluous to call to the recollection of the House, that roads are not indictable in Scotland as they are in England.

Your Committee find, also, that several attempts have been made lately to devise plans, and obtain subscriptions for repairing this road, or making a new one, and that they have all failed; partly from the magnitude of the expense, and partly from the cause alluded to in this Report, of the utility of the road (and consequently the interest about it) being

more of a general than a particular nature, such as could attach to the local proprietors situated near it.

Your Committee are thus led to the next point of inquiry; namely, the advantages to be derived from maintaining some good road between the extreme points of Carlisle and Glasgow.

Your Committee find the evils which would result from the total decay of this road, and the benefits to be derived from maintaining some good and effective road, are various and extensive, and worthy of most serious consideration. Indeed, the extent of evil on one hand, and of benefit on the other, must be manifest, when it is stated (as appears in evidence before your Committee) that the road from Carlisle to Glasgow forms the line of communication, not only generally with England and the whole West of Scotland, but also from Lancashire, Yorkshire and Wales, and all the adjoining counties, with Glasgow, Greenock and the North of Ireland, including the great trading towns of Liverpool, Leeds and Manchester. The mere mention of this extensive and complicated communication of mercantile and manufacturing correspondence and interest, branching, as it must do, in various ramifications during its whole course, cannot fail to impress the House with the immense importance, on one hand, of preserving such communication secure, and the extensive evil, on the other, of allowing it to fall into total decay. Indeed, your Committee consider this second point of their inquiry as a matter almost self-evident, and as giving rise, by its admitted importance and magnitude, to the order from the Lords of His Majesty's Treasury to Mr. Telford to make his survey and plan, and also to the subsequent charge of inquiry now entrusted to your Committee; they have therefore thought it superfluous to report upon the subject at any further length.

Your Committee have much satisfaction in stating to the House, upon the third part of their inquiry, that the survey and plan of Mr. Telford, referred to them, appears entitled to their warmest approbation. This plan proposes (agreeably to the instructions from the Treasury) to preserve as much of the existing road as can be made serviceable to the object in view, and to incur no expense which can be avoided in consolidating the new and old parts of the proposed road, in such a manner as to secure and improve the intended communication. It appears that much hilly road will be avoided altogether by the new line, many steep ascents and descents reduced nearer to a level, the entire distance shortened by nine miles *in measurement*, but reduced *in time*, by an equivalent of near twenty miles. These great advantages are rather to be estimated by their effects than described in detail; the correspondence of the mercantile and manufacturing interests at the extreme points of Carlisle and Glasgow (it is in evidence from Mr. Hasker) will thus derive the advantage of nearly half a day. The mail would arrive three hours sooner at Glasgow, and would leave it two hours later, and the ulterior places of Port Glasgow and Greenock would be benefited in a still greater proportion; to the amount, *in time*, indeed, of an entire day each post. These advantages are calculated only on the alternative between the existing bad road and the good one proposed by Mr. Telford's plan; but to state the advantages in their full extent, your Committee must call to the notice of the House the probability of the present road continuing to go from bad to worse (as it has done of late years) till it shall fall into total decay; in that case the mail from Carlisle must go round by Edin-

burgh, which would delay its arrival at Glasgow an entire day, and something more than a day, to the ulterior places of its destination.

Your Committee have already stated, that the advantages of this road are more of a general than local nature. It passes through a mountainous, pasturage and thinly peopled country, to whose immediate interest a more improved communication is of little comparative importance; from this cause, and from the exhausted state of the funds of the various trusts on this road, and the actual and hopeless debts upon it, and from the several efforts already made to repair or even uphold the existing road, having all failed already, your Committee feel warranted in stating it as their opinion to the House, that there exists no prospect of any new road or any sufficient repairs being made without the assistance of public aid.

Your Committee must observe, that a part of this line has already been recommended to the House (viz. from Carlisle to Springfield) by the Committee on Portpatrick Road, dated 13th May 1811, of which part they recommend the expense to be defrayed wholly by the public, in the following terms, 'which your Committee recommend should be wholly 'borne and paid by the public, as the counties through which the same will pass are 'already subject to an enormous charge for the support of bridges, and cannot be induced 'to contribute thereto, the same being of little benefit to them or to individuals in those 'counties, but will be of the most essential public advantage.' It appears, therefore, that the carrying this recommendation into effect, with a very inconsiderable deviation, would produce a double benefit,—that of improving the communication between Carlisle and Portpatrick, and also between Carlisle and Glasgow, to both which roads this part is common. The last stage of this road, approaching Glasgow, passing as it does through a more populous and wealthy country, seems to rest upon a very different footing from the remainder, and is not meant to be included in the general observations of this Report.

Excluding therefore this last ten miles, and also excluding the former small portion, from Carlisle to Springfield, which has been recommended to be executed by the Committee alluded to, Mr. Telford estimates the remaining expense at £.58,290. 5s. 11d., but without making any allowance for the land of the proprietors. This last point is indeed of little importance; as, it is conceived, few of the proprietors will demand any compensation, and even if they should, the land required is for the most part of little value.

To this sum of £.58,290. 5s. 11d. the amount of fencing must be added; and if a further allowance be made for other unavoidable charges, this great national benefit may probably be completed at an expense not exceeding eighty thousand pounds.

Your Committee forbear to pursue their inquiry into more minute detail; they conceive that they have stated sufficient to justify their strong recommendation of the proposed plan to the House. They have, however, thought proper to subjoin the Evidence, and Plan and Survey of Mr. Telford, by way of Appendix to their Report. From these latter documents the substance of this Report will receive much light and strong corroboration. They will not only confirm the general view of the subject which your Committee has taken, but will also establish many points of inferior detail; particularly in regard to the eligibility of the line proposed, of its easy adaptation to those parts of the old line which

have been deemed fit to retain; and also in regard to the abundance and aptitude of materials for road-making along the whole course which it is intended to pursue.

Upon the whole, it appears to your Committee, that the existing road is in such a ruinous state as to occasion much delay, and some danger, to all who travel it; that the funds have long been found inadequate to its repair, and are even, on a large portion of the line, in a state of hopeless debt; that there is no prospect of any road being made, or even the old one repaired, by the mere efforts of individuals; that the advantages of a speedy and effectual communication between the two points of Carlisle and Glasgow, embracing, as it does, such an immense tract of collateral country, are most important in kind and degree; that the contemplation of these advantages has given rise to various attempts at making a new line of road, which have all failed; that the proposed plan is calculated to improve the line of road, reduce it nearer to a level, and shorten the distance very much, while it saves time to correspondence in a still greater proportion; thus uniting all the beneficial objects without the concomitant disadvantages usually attendant upon such undertakings.

Your Committee think it only further necessary to remind the House, that public assistance has been granted in various cases, in which general accommodation and the national service have called for an expenditure beyond what the advantage to the individuals locally interested would warrant their incurring; and that if the House shall be pleased to countenance and assist the proposed plan, in any similar proportion to what it has already done in similar cases, your Committee feel confident, that very considerable exertions would be made to meet and render efficient the liberality of the Legislature; and they think it scarcely possible that public aid could be granted in any way which would produce, for a like expenditure, more accommodation to individuals, or more practical benefit to the trading, mercantile and manufacturing interests of the country.

Memorandum by Mr. *Telford.*

Previously to entering upon the consideration of the Glasgow and Carlisle Road, the reader is recommended to study the principles and directions laid down in Sir Henry Parnell's able treatise on road-making, where he will find each operation discussed in a masterly manner, and be made fully aware of the difference between a Highland and a Lowland road.

Appendix (L. 13.)

SPECIFICATIONS for making the Glasgow and Carlisle Road.

Dimensions and Formation of Roadway.

The breadth is to be thirty-four feet between the fences; of this, eighteen feet in the middle is to be metalled, and the remaining eight feet on each side are to be covered with gravel. In all embankments, the width on the top is to be thirty feet, and the side-slopes to be one and a half horizontal to one perpendicular. In all cuttings above five feet, the width between the lower skirts of the slopes is to be thirty feet; all below that depth to

be thirty-four feet. The slopes of all the cuttings to be at the same rates as the embankments. The surface of the road longitudinally, or lengthwise, in all cases where there are cuttings and embankings, are to be formed agreeably to the annexed sections; in cases where the particular sections do not apply, the ascents and descents are in no cases to exceed one in thirty, and the changes from the one to the other to be made in regular curves, to the satisfaction of the inspector. In all cases where there are side-cuttings, and a part of the road on moved ground, the surface of the lower part, or moved ground, is to be higher than that of the upper side, to allow for consolidation, so that the finished road may be of a proper form and level.

In the middle of the road there is a metal bed to be formed, and in all cases where the ground is nearly level, the metal is to be formed upon the natural surface of the ground, so as to have a curvature of four inches in the middle eighteen feet, and the sides or shouldering to be made with moved ground; but on no account is the metal bed to be cut out of the natural ground, unless it is loose gravel or rock. The metalling is to consist of two beds, or layers; that is to say, a bottom course of stones, each seven inches in depth, to be carefully set by the hand with broadest ends downwards, all cross-bonded or jointed, and no stone to be more than three inches wide on the top. These stones may be of good whin-stone, lime-stone or hard free-stone; the vacuities between the said stone to be carefully filled up with smaller stones, packed by hand, so as to bring the whole to an even and firm surface.

The top course or bed is to be seven inches in depth, to consist of properly broken stones, none to exceed six ounces in weight, and each to pass through a circular ring two inches and a half diameter in their largest dimensions. These metal stones to be of hard whin-stone; the quality of both bottom and top metal to be determined by the inspector. In every hundred yards in length on each side of the road, upon an average, there is to be a small drain from the bed of the bottom layer to the outside ditch, as shall be directed by the inspector.

Where the height of the embankment shall exceed three feet, they are to stand from one to three months, in proportion as they increase in depth, as shall be determined by the inspector.

Over the upper bed or course of metal there is to be binding of gravel, of one inch in thickness on an average. In the cross section of the finished roadway there is to be a curvature of six inches in the middle eighteen feet, and from that on each side a declivity, at the rate of half an inch in a foot, to within eighteen inches of the fences. In the remaining space of eighteen inches there is to be a curvature of three inches; making in all about nine inches on each side below the finished roadway.

In passing morassy ground, all the surface upon which the road is to be placed, that is to say, between the fences, is to be brought to a curvature of twelve inches in the middle, and all to be secured with two rows of good swarded turf; the lower one to be laid with the swarded side downwards, and the upper one with it upwards. The metalling upon the said mossy ground is to be made twenty feet in width. On all mossy ground there is

to be cut along each side of the road a drain four feet wide at the top, eighteen inches at the bottom, and three feet deep.

Cross Drains.

There are to be nine cross drains in every mile in length, placed in situations to be marked out by the inspectors; they are to be eighteen inches wide and sixteen high at the upper end, and twenty-two inches high at the lower end; their bottoms are to be paved with flat stones, or small pebble-stones, four inches in depth. The foundations of the side-walls to be laid at least six inches below the level of the bottom of the drain, and they are not to be less than eighteen inches in thickness, laid in regular courses faced on both sides in the manner of a good stone dike. The top of each is to be properly levelled, and covered with a firm turf two inches in thickness, to form a bed for the covers. The covers are to be two feet six inches in length, and four inches in thickness; their side-joints must be made strait, so as to unite closely; the parts which lie on the turf must be flat. These cross drains must be of a length not only to cross the road, but the fences on each side, also the slopes of the embankments, and pass fairly into the fields or natural watercourses. From the ends of the drain, wing-walls are to be extended five feet, in a curved direction, into the solid ground; they are to be of the same thickness as the side-walls, founded at the same depth, and carried to the same height, and coped with two rows of swarded turf. The bottom, between the wing-walls, to be paved with stones not less than six inches in depth, and well secured at the extremities by stones twelve inches in depth, and they are to be well secured at the upper ends, and connected with the firm ground and side-drains, all as expressed in the drawings made out and signed by Thomas Telford. The whole body of the drain to be laid at such a depth as to admit of a turf being laid over the covers, and the full quantity of road metal and binding, without raising the longitudinal line of road. At each end of the cross drains the water which passes along the side of the road is to be introduced by a proper opening, protected by a stone cover; this entrance to be paved at least five feet in length. In passing through morassy ground, the bottom of the drains to be laid with flat stones, quite across, and at least twelve inches under each side-wall, and to be continued quite to the extremity of the wing-walls.

General Observations.

In all cases the direction of the road is to be set out by the inspector, and all the curves made to his satisfaction; the road is always to be formed for a quarter of a mile, and examined by the inspector previous to any bottoming being set upon it; he is also to be satisfied with the bottoming before any top metal is put on, and with the top metal before any binding is put on.

Besides the sections of the principal cuttings and embankings which are annexed to this contract, there are various small irregularities of from two to three feet, which must be cut down and filled up, in order to bring the road to an uniform surface, no where exceeding one in thirty.

None of the cross drains to be covered until the inspector has examined and satisfied himself with the sufficiency of the pavements and side-walls; and the covers are also to be examined and approved of by him previous to the turf being laid on.

In passing through inclosed fields, the contractor is to keep up the cross drains until the road has been completed and taken off his hands, and also to pay the damages to fields or grounds incurred by getting materials for roads or other works, or carrying them by temporary roads.

Appendix (L. 14.)

SPECIFICATIONS for building Three Bridges on the Glasgow and Carlisle Road; *viz.*—The Hamilton Bridge, the Birkwood-Burn Bridge, and the Elvan Foot Bridge.

Hamilton Bridge.

The bridge to be placed about two hundred and fifty yards below the present old one, the precise site and direction to be determined by the principal engineer employed by the Parliamentary Commissioners. The span of the arch is to be eighty feet: it is to spring at fifteen feet above low water, and to have the rise or versed line twenty feet, and the breadth across the soffit twenty-seven feet three inches; the projections for the abutments to be determined by the plan and elevation made out and subscribed by Thomas Telford. The space for the foundations of the abutments to be excavated to two feet below the level of the bed of the river at that place, if in rock; but if at this place no proper rock or other matter suitable is found, then the said foundations are to be constructed in such a manner as the said engineer shall determine; and all expense incurred below the beforesaid depth of two feet below the bed of the river shall be considered as extra from this contract. The excavation shall extend the whole length and breadth of the foundations, as delineated upon the afore-mentioned plan, with the necessary slopes all around it, unless such solid rock is met with as shall render it unnecessary to excavate the whole thickness of the abutment into each bank; but this point is to be determined by the engineer. The ground excavated is to be deposited either between the wing-walls or as a part of the embankments for the approaches. The spaces for the foundations of the wing-walls are to be excavated by steps, as shown by the dotted lines in the elevation, to sufficiently firm ground. The masonry of the abutments is to be laid at the aforesaid depth of two feet below the lowest part of the bed of the river; it is to be thirty-five feet in length and seventeen in breadth, and to diminish, as shown in the drawing, to thirty-one feet three inches in length, and to fifteen feet in breadth at the springing. The outside facing of the front and ends of the abutments for three feet in thickness on an average, including bond-stones, to be laid in regular courses, breaking joint at least nine inches; these courses are to be from ten to eighteen inches in thickness; the stretchers to be from two to four feet in length, and not less than two feet in breadth at least; one-sixth part of the face to be bond-stones, not less than one-sixth in the face and three-sixths in length into the wall; they are to be worked with chisel-drafts, both round the face and beds, and be neatly scabled or broached between these drafts; the end joints are to be squared for twelve inches back. The remaining thickness of the abutments is to consist of stones

scabled into a square shape, and also laid in regular courses, properly bonded with the outside stones and with each other; immediately below the springing, there is to be a string-course one foot in thickness, which is to project two inches, and upon that, properly labelled springers, not less than eighteen inches in thickness and three feet six inches in length into the wall; these springers are to be supported and backed with large well-scabled square stones, quite through the abutments. The arch-stones are all to be three feet in depth in the beds, from two to four feet in length on the soffit or face, and from eighteen to twelve inches in thickness; they are to be laid, each course of one thickness, quite through the arch, the thickest courses to be laid next the springing, and corresponding courses on each side of the arch; all the arch-stones are to be worked with chisel-drafts, and neatly broached or scabled between these drafts; they are each to have a chamfer of one inch and a half along the head and bed joints, and each is to break joint at least one foot, to be well flushed in mortar, and brought firmly to its bed by a wooden maul; after the arch has been keyed, and before the centre is struck, the whole shall be wedged with slate, and the top-joints carefully grouted. At the back of the arch, the masonry backing is to be carried up, for the whole thickness of the abutment, for ten feet above the springing. The outer spandril walls are at the said heights to be four feet in thickness, and to diminish gradually, by offsets on the inside, to two feet at the level of the top of the arch; the outside facing is to consist of regular courses, chisel-drafted, and scabled or broached; the stretchers to be not less than fifteen inches in breadth, and one-sixth of the face to be headed not less than two feet six inches in length into the wall; the joints to be all regularly broken; the thickness of the courses may vary from fifteen inches below to ten inches at the top, but to be of corresponding thicknesses on each side of the arch; the remaining thickness of the walls to consist of good rubble-work, laid in a regular manner and bonded with the front stones and each other. Besides these outside spandril walls there are to be three interior walls, on each side of the arch, as shown in the plan; they are to be of good rubble-work, laid in a regular manner; they are to be two feet in thickness at ten feet above the springing, and to diminish to eighteen inches at three feet six inches below the level of the roadway; along the abutments, immediately behind the line of the lowest arch-stone, there is to be a wall of similar rubble-work with the last-mentioned; it is to be three feet in thickness at the bottom, and two feet at three feet six inches below the level of the roadway; it is to be properly bonded with them; at this height, all the spaces between these walls are to be covered, either with small arches nine inches thick, with rising spandrils filled with masonry, or flat stones, one foot in thickness, well jointed, and to have at least six inches bearing; there are to be apertures through each of the walls, to admit of a person passing into all the spaces; there are also to be at least three stones across each aperture at proper heights, to steady and connect the walls upon each abutment. At the distance of four feet from the last-mentioned cross-wall there is to be another, two feet in thickness; it is to commence at ten feet above the spring, and be carried to the height of seven feet, and there the space between the walls is to be arched over by stones nine inches in depth. The wing-walls are to be forty-five feet long at the top, measured from the front of the abutment at the springing, and forty-two feet six inches at the level of the roadway; they are to be ascended by steps, as shown by the dotted lines on the elevation; they are to be six feet

in thickness at the lowest part behind the abutment, and to diminish gradually by offsets on the back side to two feet at eighteen inches below the level of the roadway; their outside is to be laid in regular courses, *chisel-drafted*, and neatly scabled or broached between the drafts; the headers and stretchers are to be as described for the spandrils; the backing is to be good rubble-work, as described for the spandrils; the pilasters and *newels* are to correspond with the plan and elevation; the panels and passage-entries are to be neatly chiselled. At the back of each wing, about the middle of its length, there is to be a buttress or counter-fort of good rubble-work properly bonded into the main wall; it is to be founded as low as that wall, and there is to be four feet of projection and three of thickness, and to diminish by regular offsets all round to one foot square, at four feet below the roadway. Near the extremity of the wing-walls there is to be a cross wall, of good rubble-work; it is to be founded as low as the wing-walls, and properly bonded into them; it is to be four feet in thickness at the foundations, and to diminish by regular offsets on each side to two feet at four feet below the level of the roadway. At eighteen inches below the top of the finished roadway there is to be a fascia course and cornice, making together eighteen inches in thickness; these are to consist of stones, at least eighteen inches in breadth, besides the projection over the face of the walls, pilasters and newels; they are all to be neatly chiselled, and to extend to the extremity of the wing-walls, as shewn in the elevations. Upon the top of the cornice there are to be parapets extending along the arch pilasters, wing-walls and newels; they are each to consist of a plinth, dado and coping, making in all four feet in height above the cornice, and also the sides of the finished roadway; these parapets are to be neatly chiselled and jointed. The plinth is to consist of one course, one foot in height, and fourteen inches and a half in breadth; the dado of two courses, each one foot three inches in height, and twelve thickness; the coping one course, fourteen inches and a half in breadth, and six inches in thickness; it is to be cut with a weathering of one inch, a half each way from the middle of the top, which will leave a square nosing of four inches and a half; none of the coping stones are to be less than three feet in length; in the middle of each joint there is to be a cast-iron dowel, four inches in length, and one inch and a quarter square, run with Parker's cement; the copings for the pilasters and newels are to be of suitable dimensions, to answer the projections and small extra rise; the parapets and roadway are to have a general curve between the extremities, of one in thirty-six; the clear breadth between the dado parts of the parapets is to be twenty-five feet; there is to be a footpath of smoothed and well-squared pavement on each side, three feet five inches in breadth, within the plinths of the parapets; the surface of this is to be three feet ten inches below the top of the coping; there is to be a row of curb-stones next the roadway, fifteen inches in depth, and one foot in breadth, with a slope or level on the outer edge of two inches in six of depth; these stones are to be neatly chisel-drafted and jointed, to be not less than three feet in length, and each joint to be secured by a cast-iron dowel, as described for the coping of the parapet; the outer edge of this curbing is to be rounded. The space at the back of this curbing is to be filled up with clean rough water-gravel or stone rubbish, well rammed and grouted with lime mortar, upon which hard stone pavement, not less than three inches in thickness, is to be laid in lime mortar; the pavement is to be well squared; the face is to be chisel-drafted and neatly broached; the upper surface is to have a slope

See Note, p. 193.

See Note, p. 194.

towards the roadway of one inch in the whole breadth. The whole of the masonry of every part of the bridge is to be laid in mortar, composed of one part of good lime, and two of clean sharp sand from the Clyde, well mixed and beat together; each stone is to be laid flushed in mortar, and brought firmly up to its bed, and this applies to both the square masonry and rubble; the joints in the fronts and return of the abutments, as far as the water-wings, and as high as the lower side of the string course under the springers, are all to be pointed with Parker's cement. From the extremity of the wing-walls, rubble-walls, also laid in lime mortar, are to be extended in the same horizontal curve as the wings, and diminishing in height to suit the slope of the earthen banks of approach; they must be four feet six inches thick at the foundation, at the newel, and diminish to two feet at the top and extremities; they are to be coped with stones two feet in breadth and nine inches in thickness, chisel-drafted and broached, and there is to be a small newel at each extremity, as shown in the plan and elevation. Above and below each abutment there are to be water-wings, walls of good rubble-work laid in lime mortar, fifteen feet in length and ten feet in height, above low-water in the river; they are to be founded at two feet below the level of the bed of the river, where they are to be four feet in thickness; they are to diminish by regular offsets on the back side to two feet at the top; they are to be coped with stones two feet in breadth and one in thickness, and the outside joints are to be pointed with Parker's cement. The spaces between the wing-walls are to be filled with rough water-gravel or stone rubbish, up to the general circle for the bottom of the roadway, upon the top of the arch-stones; here the roadway shall be formed by laying two rows of swarded turf over the whole of covered archways and the aforesaid gravel, and upon the one with the swarded side down and the other up, making together four inches; a bed of stones of proper quality, broke so as none shall exceed six ounces in weight, after these are beat into a solid body and covered top surface, so that they shall be fifteen inches thick in the middle of the roadway, and ten inches at the edge of the curb-stones on each side; there shall then be laid a blinding and finishing layer of good binding gravel two inches thick on an average, which shall be condensed by passing a heavy roller over it.

Birkwood-Burn Bridge.

The bridge is to be placed about fifty yards below the old coal-pit on the south bank; the precise site to be determined by the chief engineer employed by the Parliamentary Commissioners. It is to consist of three semicircular arches of thirty feet span each; the breadth across the soffits, at the crowns, to be each twenty feet three inches. The general form and dimensions to be agreeable to a plan and elevation made out and subscribed by Thomas Telford.

The southern abutment is to be sunk to two feet below the lowest part of the bed of the burn at that place. The masonry of this south abutment is to commence at the aforesaid depth of two feet below the bed of the burn, where it is to be twenty-five feet two inches in length, and eight feet in breadth; it is to be carried up to fifty feet in height from the bed of the burn; the front is to batter one foot in the height, besides the offsets at the base, and to diminish by offsets on the back side, so that its thickness at the springing shall be five feet. The sides are to batter each two feet, besides the said offsets, and are

to be twenty-one feet four inches at the springing. All the masonry is to be chisel-drafted, and neatly scabled, or broached between the drafts, and laid in regular courses properly bedded, jointed, and bonded quite through the work. The pier which will stand immediately on the north side of the burn to be founded at the same depth, and to be the same in respect of dimensions and workmanship, as what has been described for the abutments, only it is to be four feet in thickness at the springing. The second pier and the north abutment, which will be placed on the face of the north bank, will be of the same dimensions at the springing, and incline downwards in the same ratio as those already described, to where a proper foundation can be met with, as shown in the elevation. The arch-stones are to be two feet in depth; to be chisel-drafted, and neatly scabled or broached, laid in regular courses, each course to be the same thickness through the body of the arch, and may vary in thickness from twelve to nine inches; the thickest courses to be laid next the springing, and of corresponding thicknesses on each side the arch; they are to have chamfers of one inch and a quarter along the heads and bed joints. The spandrils are to be four feet in thickness at the springing, and to diminish to two feet at the level of the top of the arch-stones; the outside of the spandrils, as well as the arches, are to batter at the same rates as the ends of the piers and abutments, and the remainder of the diminution is to be on the back side by regular offsets; the outside is to be drafted by headers and stretchers, and scabled ashlers to correspond with the piers; the backing to be of good rubble-work, well bonded with the front ashlers, between the arches and over the abutments; the rubble backing to be carried up seven feet six inches above the springing, and thence sloped to the back of the arches, as shown in the elevation. The wing-walls are to be founded by offsets into each bank, as shown in the plan and elevation, so that they shall be upon firm rock or sound ground; their thickness to be as shown upon the plan; the outside is to be of drafted and scabled ashler and rubble-work, as described for the spandrils. Upon the level of the top of the arch-stones there is to be laid a Fascia course and square capping, making together eighteen inches in thickness, and eighteen inches in breadth, not including the projections; they are to be neatly chiselled, and the capping is to have a weathering of one inch in the breadth of the projection. Upon the whole length near the arches, and along the wing-walls, there is to be a parapet on each side; it is to consist of a plinth, dado and parapet, making together three feet eight inches in height. The plinth is to be ten inches in height, and fourteen and a half inches in thickness; the dado is to be two feet four inches in height, and twelve inches in thickness. The coping is to be six inches in thickness, and fourteen and a half inches in breadth; the top of the coping to have a weathering of one and a half inch on each side, which will leave a square nosing of four and a half inches. The whole of the parapet is to be squared ashlers, with chisel drafts, and neatly broached between the drafts; each joint of the coping is to be secured with a cast-iron dowel four inches long and one and a quarter square, let into the middle of the joint, and run with Parker's cement. The spaces between the spandril and wing-walls to be filled with stone rubbish to the level of the top of the arches. Over the arches and spandrils there is to be a bed of clay six inches in thickness well beat, and upon a roadway, agreeable to the general specification. Immediately above and below the base of the south abutment, and pier next to it, there

are to be water-walls fifteen feet in length; they are to be founded at the same depth as the south abutment, and carried to the height of five feet above the level of the bed of the burn; they are to be of good rubble-work, four feet thick at the bottom, and two at the top, and to have a coping two feet in breadth, and not less than nine inches in thickness. All the masonry is to consist of sound stone which will stand the effects of the weather; it is all to be laid in mortar, composed of one part of good lime, and two of clean sharp sand, well mixed and beat together, and each stone is to be laid flushed in mortar, and brought firmly to its bed.

ELVAN FOOT BRIDGE.

The bridge to be placed in the situation marked by the inspector; it is to consist of one arch, ninety feet span, twenty-five feet rise, and twenty and a quarter feet across the soffit. The foundation for the abutment on the east side is to be sunk for the whole of its breadth into the rock as low as the bed of the river at that place, unless the inspector is satisfied that the foundation is sufficiently good at a less depth; when the rock has been excavated to this depth and properly levelled, the masonry is to be laid, and brought up six feet above the level of low summer water to the springing of the arch; it is to be fourteen feet in thickness at the foundation, and twelve feet at the springing; the length at the foundation will be twenty-nine feet, and twenty-six feet six inches at the springing. On the western side of the river, the foundation for the abutment is to be sunk to the depth of two feet below the level of low summer water, and if rock is not found at this depth, there are to be piles and a proper platform, but these, as well as all the materials and labour, directed by the inspector to be employed under the said two feet, are to be paid for extra from the contract. The masonry of this abutment is to be of the same dimensions as mentioned for the one on the eastern side. The outside stones of the abutments are to be of durable freestone, to have chisel-drafts round the face, beds and end joints, and neatly scabled or broached between the drafts; they are to be laid headers and stretchers; none of the stretchers to be less than fifteen inches in breadth on the bed; and one-sixth part of the face to be headers, not less than two feet six inches in length; the end joints to be squared full back, at least six inches from the face. The backing may be of good whin-stone, hammer-dressed, and laid in a regular manner, bonding with outside stones, and each other. The arch-stones are to be three feet six inches in depth; they may be from ten to eighteen inches in thickness, the thickness to be next the springing; they are to be laid in regular courses quite through the soffit or body of the arch, bending at least twelve inches, and each stone brought firm to its bed by a wooden maul. These arch-stones are to consist of sound hard durable freestone, having chisel-drafts round the face, heads, beds and joints, and be neatly scabled or broached between the drafts; they are also to have small chamfers along the heads and bed joints, quite across the soffit; the whole to be set upon a centre of proper scantling and framing, carefully set and braced, all to the satisfaction of the inspector. The wing-walls to be founded on firm ground, at least three feet under its surface, and to be thirty-three feet in length; they are to extend three feet before the front part of the abutment on each side, on purpose to admit of the Fascia course along the whole height of the bridge, as shewn in the plan and elevation. These wing-walls are to be five feet in thickness at the level of the springing, and diminish to two feet at

the level of the roadway; the spandrils are to be of the same thickness as the wing-walls at the same heights; both wing-walls and spandrils are to be of good whin-stone, the outsides to be hammer-dressed, and laid in regular courses, without any joinings in the front beds or end joints; all the backing to be laid in a regular manner, well bonded with the front stones and each other. The back part of the abutments to be carried up ten feet above the level of the springing of the arch, and then to be sloped up and connected to the back of the arch-stones, as shewn in the section; there is also a wall to be built on the back part of the abutment up to within three feet of the bottom of the road metal; it is to be three feet in thickness at the foundation, and two feet at the top, all as shewn in the plan and by dotted lines in the elevation; it is to be of good whin-stone, laid in a regular manner, and well bonded with the wing-walls. Towards the extremity of the wings there is to be another cross-wall of similar dimensions, materials and workmanship. At the level of the top of the arch, and in the line of the declivity of the roadway, there is to be a string course of squared freestone, laid, as shewn in the elevation, along under each parapet; they are to be two feet in breadth, and one foot in thickness. The parapets are to be three and a half feet in height above the finished road, and to consist of a plinth nine inches in thickness, and fifteen inches in breadth. The dado is to be twelve inches in thickness. The coping is to be six inches in thickness, and fifteen inches in breadth, that is to project two inches on the outside, and one on the inside; it is to have a square nosing of four and a half inches, and a weathering on each side of one inch and a half. The whole of the parapets are to be hard durable freestone, to have chisel-drafts round their faces, beds and end joints, and neatly scabled or broached between the drafts; each joint of the coping is to be secured by a cast-iron dowel, four inches long, and one inch and a quarter square, run with Parker's cement. The water-wings are to be twenty feet in length, and three feet in thickness at the foundation, besides the counterforts, and two feet at the top; they are to be founded one foot below the bed of the river, and carried as high as the springing of the arches, and coped with two rows of swarded turf. All the masonry to be laid in mortar, made of one part of good lime, and two of sharp clean sand, well mixed and beat.

Between the spandrils and also the wing-walls, the space is to be filled up with stone, rubbish or coarse gravel, up to the level of the top of the arch; at this height there is to be laid a bed of clay nine inches in thickness, well beat, over the whole space between the spandrils and wing-walls, also over the arch crown; over this, there is twelve inches of road top metal to be laid, and above all a binding of gravel two inches in thickness on an average. The approaches to the bridge to be embanked, so as to have an inclination of one in twenty-seven on the east side, and one in twenty on the western side. These embankments, and the roadway upon them, to be, in respect to materials, form and dimensions, according to the regulations for general road-making, and the whole made agreeably to the plan, elevation and section prepared and signed by Thomas Telford.

Appendix (L. 15.)

HEIGHTS above the Toll-House at the Eastern Entrance to *Glasgow*: The said Toll-house deemed to be at level of high water.

	Feet.
Road opposite Bothwell (North of Bridge)	130
Road North of Hamilton	142
Laverock-hall	290
Nethan Water at Lismahago	444
Douglas Water, near the Mill	509
Summit South of - ditto	922
Duncatton Water	731
Summit South of ditto	835
Abingdon Village	756
Crawford ditto	810
River Clyde at Elvanfoot	807
Summit of Country South of ditto	984
Cross the Evan Water, Upper Bridge	870
Boundary Counties of Lanark and Dumfries	660
Beattock Inn at Dumfries and Edwin Road	341
River Annan at Woodfoot	209
Bield Toll	210
Dinwoodin Green	172
Lockerley	132
Summit between ditto and Ecclefechan	363
Ecclefechan	90
Summit South of ditto	187
Summit South of Kirtle Bridge	251
Springfield Village	60
Sark and Esk Bridges, below the level, being in the tideway.	—
Stanwix Bank above	43

Appendix (L. 16.)

SPECIFICATION for furnishing Whin Metal for the Repair of the *Glasgow* and *Carlisle* Road; with the Quantities and Expense thereof in each Section of the Road.

The contractors shall furnish and lay down in walled depôts, or in places to be pointed out by the trustees or their surveyor, at least in ten different parts in each mile, to be put on the road with barrows by the men that work on the surface of the road, such number of cubic yards of whin metal for each mile that the road may require yearly. The metal to be of the best blue or red whin, as may be specified for each mile or division of road. All

the metal to be broken and ready for measurement by the first day of October yearly. The metal shall be taken from quarries, fields or beds of rivers, which shall be pointed out by the trustees or their surveyor. No stones to be taken from fields or beds of rivers, or from quarries that are too small to be broken through the middle. All the stones that are taken from fields, beds of rivers or quarries, must be collected by the hand and put into the carts without shovels or any implement in the hand; and all the stones must be broken down in a proper manner, so as no stone shall exceed four ounces English, and they must all be broken so small as to pass through a circular ring of one inch and a half diameter in their largest dimensions. As the contractors are only to be bound to furnish and break the metal, the surveyor is to be the sole judge of the quality of the metal, and also of the size. If any of the contractors fail at any time in not providing and breaking the metal at the proper season when ordered by the surveyor, the surveyor shall have it in his power at any time to furnish and break the metal at the contractor's expense without the necessity of applying to any court of law. And further, the contractor shall be bound to furnish any additional quantity of metal that the trustees or their surveyor may require them to do, in writing, over and above the stipulated quantity for any mile or division of road, at the same rate per cubic yard as the contract price. And further, the trustees shall have it in their power to lessen the quantity of metal for any mile or division of road, and the contractors shall be bound to adhere to the same so soon as the trustees or their surveyor may order them in writing. And if the stones are not all broken and ready for measuring by the first day of October yearly, the surveyor shall have it in his power to take possession of such stones as may be broken, without paying any thing therefor. If the surveyor shall find at any time that earth, gravel, soil, or any rubbish of any kind, is put into any of the heaps of broken stones, or any thing done on purpose to deceive him, he shall have it in his power to forfeit all the stones without applying to any court of law. The surveyor shall have it in his power to order what quantity of stones he may think proper to be put down on each mile of road, or on any part of the mile or division of road, so that it is not to be understood that an equal quantity is to be put down in each place, but must be laid down in such quantities as may be ordered, and in such places.

The contractors shall pay all surface damages that they may do to fields or in beds of rivers, by taking out metal or carting the same to the road; the contractors shall have the benefit of the Act of Parliament for that purpose. The contractors are not to be allowed to turn over the metal in the depôts after it is broken.

The money to be paid quarterly, in equal portions, by a certificate or order, under the hand of the surveyor.

The furnishing of the metal is in general let by contract, for two or three years at a time.

As the stones are all let to be furnished and broken by the cubic yard, and are in general put on by wheelbarrows by the men who work by the day on the surface of the road, the metal is put on the road to a better purpose.

The surface of the roads in this part of the country is in general kept by men who work by the day; one man keeps from one to five miles, just according to the travel on the road. The men are employed in keeping the surface clear of mud in soft weather; their employment in dry weather is to take off the loose rolling stones, and dress up the sides of the roads and side drains.

During the whole progress of these extensive improvements, the Glasgow Committee, under the liberal and judicious management of their chairman, Mr. Kirkman Finlay, persevered in enabling me to bring this road into a very perfect state; they annually, in company with my deputy, John Pollock, perambulated the whole distance from Glasgow to Carlisle, noting the most essential improvements to be performed in that year; which, being thus directed and afterwards witnessed by themselves, became interesting to them; and by allowing the accruing tolls to be expended in furtherance of the work from time to time they greatly facilitated its progress.

T. T.

The QUANTITIES and EXPENSE of MATERIALS for REPAIRS.

Sections of Road.		Broken Stones.	At per Yard, Rate.		Number of Men in Winter.	Number of Men in Summer.
		Cubic Yards per Mile.	s.	d.		
1.	From Govern Burn near Hamilton, to Birkenshaw - - - - - -	120	5	6	3	1 ½
2.	Six miles South of Birkenshaw - -	90	5	6	3	1 ½
3.	Six miles South of Lismahago - -	80	4	4	3	1 ½
4.	Nine miles from Douglas Mill - -	100	4	2	4	2
5.	Five miles and a half from Abingdon to Elvanfoot	80	3	3	2	1
6.	Eight miles from Beattock - - -	60	3	–	4	2
7.	Six miles to Lockerbie - - -	90	3	–	2	1
8.	Seven miles and a half to Ecclefechan -	90	3	–	2	1
9.	Five miles to Woodhouse - - -	100	3	8	1	1
10.	Ten miles to Sark Bridge - - -	100	3	8	1	1
	The different divisions cost from £.20 to £.46 per mile.					

APPENDIX (L. 17.)

LANARKSHIRE ROAD.

SPECIFICATION for BRIDGE over CANDER WATER.

THIS bridge is to be placed in the situation to be marked out by the inspector; it is to consist of three arches thirty-five feet span each, and seventeen feet five inches rise each; the breadth across the soffit, at the crown of the arches, to be twenty feet three inches; the whole height, from the surface of the river channel to that of the finished roadway, to be sixty-four feet.

The foundations of the two piers to be sunk to the depth of two feet below the lowest part of the bed of the river at that place, and more, if required by the engineer or his deputy; but all below the two feet to be paid, extra from the contract, by a fair valuation. The space for the foundation to be quite sufficient to receive the masonry, with the necessary slopes. The masonry of the piers is to commence at this depth, where each will be twenty-four feet three inches in length, and eight feet in breadth; they are to be carried up to ten feet above the surface of the river channel, where there must be a chamfered scarcement, all round, of six inches; from thence the shaft must be carried to the impost under the springing of the arches, as represented in the elevation: the taper or diminution of these piers, as well as the shape and dimension of the impost, are delineated on the drawings; also the arch-stones, parapets, &c.

The masonry of the piers is to consist of squared ashler, having chisel-drafts round each face and bed, and be neatly scabled or broached between; the end-joints are to be full and square; the whole of the masonry is to be laid in regular courses through the whole body of the work, properly bonded; the foundations of the abutments are to be laid at such depth as ensures firm ground.

The arch-stones are to be two feet six inches in depth or breadth on the bed, laid in regular courses; each course to be of the same thickness throughout; their thickness to vary from twelve to nine inches; the thickest courses to be nearest to the springing; all to be laid in good lime mortar, and each stone to be brought to its bed by a wooden maul.

The wing-walls are to be founded and brought up of the form and dimensions shown in the elevation. All the outside stones of the abutments, wing-walls and spandrils are to have chisel-drafts round the face beds and end-joints, and be neatly scabled or broached between the drafts; the whole to be laid headers and stretchers; the stretchers to be not less than twelve inches broad on the bed, and the sixth part of the surface to be headers not less than two feet in length; these dimensions are applicable to the outside stones of the piers.

All the backing is to be hammer-dressed stones, laid in regular courses, bonded with the front stone and with each other; the backing to the arches to be of a similar description, and carried up to the height shown in the elevation in dotted lines.

At the top of the arch-stones there is to be a string-course laid over the arches, spandrils and pilasters, as shewn in the elevation; it is to project four inches, have breaks at the pilasters, to be twelve inches in thickness and eighteen inches in breadth; along the top of this string-course there is to be a course of stone six inches in thickness and nineteen inches in breadth; the parapets are to be four feet in height above the finished roadway; to have a plinth course, fourteen inches in breadth and nine inches in height. The dado part is to be twelve inches in thickness. The coping is not to be less than six inches in thickness, with four inches and a half square nosing and one inch and a half weathering on each side; on the top they are to be fifteen inches in width, that is, to have a projection of one inch on the inside and two on the outside; each joint of the coping to be secured by a cast-iron dowell, four inches long and one inch and a half square, run with Parker's cement. The whole of the string-course and parapets to be neatly squared and jointed.

The water-wings are to be twenty feet in length, to be founded one foot below the bed of the river, and be carried five feet above it, inclusive of a coping of large flat stone; the counterforts are to be three feet square, and of the same height.

The cross or tie walls between the wing-walls are to be of good rubble masonry, laid in regular courses; they are to be founded on the natural ground; at the bottom they are each to be five feet in thickness, and reduced by regular offsets to two feet six inches at the under side of the road top metal. All the masonry of this bridge is to be laid in good lime-mortar, made of one part of lime and two parts of clean sand, well mixed and beat; the spaces between the spandrils and wing-walls to be filled up with coarse gravel or dry stone rubbish, from the top of the masonry to the under side of the bed of clay.

Over the top of the arch and space between the wing-walls there is to be laid a bed of clay six inches in thickness, well beat; over this, there is to be twelve inches in thickness of hard whin-stone, or lime-stone broken to the size for road top metal.

APPENDIX (L. 18.) - - - - - -

SCOTTISH HARBOURS. - - - - - - - - -

FINAL ACCOUNT of MONEY RECEIVED and DISBURSED by the COMMISSIONERS for HIGHLAND ROADS
SCOTLAND, towards making Canals, Harbours and

Drs - From 16th May 1807 to

		£.	s.	d.
1807. May - 16	To Cash received from Barons of Exchequer in Scotland - -	12,931	-	-
Aug. - 10	To one year's Interest on Debt of £. 9,000, (at 5 per cent.) received from the City of Edinburgh - - - - - - -	450	-	-
1808. Sept. - 13	To ditto - - - ditto - - - ditto - - - - - -	450	-	-
1809. Aug. - 9	To ditto - - - ditto - - - ditto - - - - - -	450	-	-
1810. Sept. - 12	To ditto - - - ditto - - - ditto - - - - - -	450	-	-
	To Cash received from the City of Edinburgh in part of the said Debt - - - - - - - - - - - - - -	1,000	-	-
1811. Sept. - 4	To one year's Interest on Debt of £.8,000 from ditto - - -	402	12	-
1813. Jan. - 4	To Cash received from the Barons of Exchequer in Scotland (including Interest on £.8,000, formerly received from the City of Edinburgh) - - - - - - - - - -	4,301	10	6
Mar. - 3	To Overcharge for Income Tax on the above, refunded - -	48	13	2
Sept. - 16	To one year's Interest on £. 8,000 (at 5 per cent.) received from the City of Edinburgh; less £. 40 for Property Tax - -	360	-	-
1814. Sept. - 14	To ditto - - - ditto - - - ditto - - - - - -	360	-	-
1815. Sept. - 15	To ditto - - - ditto - - - ditto - - - - - -	360	-	-
1816. Sept. - 20	To ditto - on £.24,000, after deductions - - - - -	1,112	4	5
1817. Mar. - 29	To half a year's Interest on ditto - - - - - - -	552	10	-
Sept. - 5	To ditto - - - ditto - - - - - - - - - - -	552	10	-
Dec. - 19	To Cash received from the City of Edinburgh in part of said Debt - - - - - - - - - - - - - -	20,000	-	-
	To Interest on - - ditto - - - - - - - - -	452	16	10
1818. Sept. - 4	To Cash received from Barons of Exchequer in Scotland - -	4,055	6	-
1824. Mar. - 25	To Interest on Deposits in the Bank of Scotland to this date -	2,230	17	4
	To ditto - on Exchequer Bills received at sundry times - -	2,719	4	7
	To Cash gained by Remittances to Scotland at sundry times -	57	15	9
	To Cash received from the Account of Roads and Bridges - -	34	19	5
	£.	53,332	-	-

Memorandum:—The aid granted to sundry Harbours and other similar improvements, as above specified, amounts to less than £. 100,212; and as the parties had also to complete the work, although it might exceed the estimated expense (or or double the above Total, management

APPENDIX (L. 18.)

SCOTTISH HARBOURS.

and BRIDGES, under the "Act for applying certain BALANCES arising from the Forfeited Estates in other Public Works there;" 46 Geo. III. c. 155.

25th March 1824. - Crs.

		£. s. d.	£. s. d.
	By Payments towards the Improvement of:—		
	Avoch Harbour - - -	527 17 –	
	Ballintraed Harbour - - -	1,166 7 9	
	Banff Harbour - - -	7,973 10 –	
	Burgh Head Harbour - - -	2,000 – –	
	St. Catherine's Pier - - -	83 10 –	
	Channery Pier - - -	646 2 –	
	Cullen Harbour - - -	2,070 9 7	
	Dingwall Canal - - -	1,904 2 1	
	Fortrose Harbour - - -	2,007 13 3	
	Frazerburgh Harbour - - -	5,277 17 7	
	Gourdon Harbour - - -	994 18 8	
	Invergordon Piers - - -	819 14 –	
	Jura Small Isles Pier - - -	373 10 –	
	Kiels Pier - - -	118 16 5	
	Kirkwall Harbour - - -	1,972 2 2	
	Kyle Rhea Piers - - -	585 10 –	
	Peterhead - South Harbour - - -	3,900 – –	
	Peterhead - North Harbour - - -	11,572 4 –	
	Nairn Harbour - - -	1,862 10 10	
	Portmaholmach Harbour - - -	1,584 9 2	
	Portree Harbour - - -	346 4 8	
	Tarbet Harbour - - -	863 11 9	
	Tobermory Harbour - - -	1,455 5 4	
			50,106 6 3
	By Payments to Mr. Rickman, as Secretary to the Commissioners, from 1807 to 1822 - - -	- - -	755 – –
	By - ditto - to Mr. Hope, W. S., for Law Charges - -	- - -	1,074 6 2
	By - ditto - to Mr. Telford, Engineer - - -	- - -	471 2 –
1818: Jan. 13	By Payment to Charles Moodie, Clerk in the Audit Office, the price of his Annuity of £.50 per annum, allowed him by the Barons of the Exchequer - - -	530 10 4	
	By - ditto - to William Allen, Porter - ditto of £.20 per annum - - -	184 13 8	
	By - ditto - to Sir John M'Lean, K.C.B., Proprietor of the inn at Dalwhinnie, the sum calculated to be equal to six years' rent still due by the lease - - -	131 3 7	
	Paid by the Commissioners to liberate the principal Sum retained by the Barons of the Exchequer - - -		846 7 7
	By Payment to the Road Repair Account, being the Balance of Mr. Telford's Scottish Harbour Account - - -	- - -	78 18 –
		£.	53,332 – –

James Smith, Accountant,
29, Princes-street, Bank.

£. 50,106; and being always granted on condition of equal amount expended by the applicants, shews an Expenditure of not they might be induced to carry the improvement farther), the Total Sum expended cannot have been less than £. 106,664; and superintendence included.—*J. R.*

APPENDIX (M.) - - - - - -

ADDITIONAL CHURCHES in the - - - - - - -

NAME OF PLACE.	Parish or Island.	County.	Population in the Vicinity.
1. Loch Gilphead - - - - - -	Glassry - -	Argyle - -	2,500
2. Muckairn (*Manse only*) - - - - -	Muckairn - -	- ditto - -	830
3. Duror - - - - - - - - -	Appin - -	- ditto - -	650
4. Kilmeny (*Manse only*) - - - - -	Islay Island -	- ditto - -	2,500
5. Portnahaven - - - - - - - -	- ditto - -	- ditto - -	1,500
6. Oe or Oth - - - - - - - -	- ditto - -	- ditto - -	2,000
7. Kinloch-Spelore - - - - - -	Mull Island -	- ditto - -	500
8. Salen (*Manse only*) - - - - -	- ditto - -	- ditto - -	850
9. Tobermory - - - - - - - -	- ditto - -	- ditto - -	2,000
10. Ulva - - - - - - - - -	Ulva Isle - -	- ditto - -	900
11. Iona - - - - - - - - -	Iona Isle - -	- ditto - -	1,000
12. Strontian - - - - - - - -	Ardnamurchan -	- ditto - -	1,500
13. Acharacle - - - - - - - -	- ditto - -	- ditto - -	700
14. North Ballachulish - - - - - - -	Kilmallie - -	Inverness - -	600
15. Ardgour (*Church only*) - - - - -	- ditto - -	Argyle - -	400
16. Rothiemurchus (*Manse only*) - - -	Rothiemurchus	Inverness - -	1,000
17. Tomintoul - - - - - - - -	Kirkmichael -	Banff - - -	600
18. Inch (*Manse only*) - - - - - -	Kingussie - -	Elgin - - -	600
19. Steinsholl - - - - - - - -	Skye Isle - -	Inverness - -	1,700
20. Halen in Waternish - - - - -	- ditto - -	- ditto - -	1,000
21. Trumisgarry - - - - - - - -	N. Uist Isle -	- ditto - -	1,150
22. Berneray Isle - - - - - - - -	Harris - -	- ditto - -	1,000
23. Plockton - - - - - - - -	Lochalsh - -	Ross-shire - -	600
24. Shieldaig - - - - - - - -	Applecross - -	- ditto - -	800
25. Carnoch in Strath-Conan - - - - -	Contin - -	- ditto - -	1,200
26. Kinloch-Luichart - - - - - - -	- ditto - -	- ditto - -	700
27. Poolewe - - - - - - - - -	Gairloch - -	- ditto - -	1,500
28. Croich - - - - - - - - -	Kincardine - -	- ditto - -	500
29. Ullapool (*Church only*) - - - - -	Loch Broom -	- ditto - -	2,000
30. Cross, Ness District - - - - - -	Lewis Isle - -	- ditto - -	1,500
31. Knock, Eye District - - - - - -	- ditto - -	Ross-shire - -	1,450
32. Rhuestore - - - - - - - -	Assynt - -	Sutherland - -	1,400
33. Kinloch-Bervie - - - - - - -	Edrachilles - -	- ditto - -	1,000
34 Strathy - - - - - - - - -	Farr - - -	- ditto - -	1,000
35. Berridale - - - - - - - -	Latheron - -	Caithness - -	1,750
36. Keiss - - - - - - - - -	Wick - - -	- ditto - -	1,100
37. Deerness (*Manse only*) - - - - -	Deerness - -	Orkney - -	700
38. N. Ronaldsay, Skilperhall (*Manse only*) -	Cross and Burness	- ditto - -	560
39. Sandwick (*Manse only*) - - - - -	Dunrossness -	Shetland - -	650
40. Quarff - - - - - - - - -	Quarff - -	- ditto - -	840
41. Innerwick in Glenlyon (*Manse only*) -	Fortingall - -	Perth - - -	1,000
42. Rannoch (*Manse only*) - - - - -	- ditto - -	- ditto - -	1,650
43. Kirktown of Foss (*Manse only*) - -	Dull - - - -	- ditto - -	800
		TOTAL - - -	48,180

- - - - - - APPENDIX (M.)

- - - - - - - HIGHLANDS and ISLANDS of *Scotland*.

EXPENDITURE ON CHURCHES AND MANSES.

	£.	s.	d.
Contract price, £. 1,470; levelling and draining, £. 4. 14. 2.	1,474	14	2
Church rebuilt by General Campbell, of Loch Nell, at an expense of £. 993. 14. 6.; Manse, at the expense of the Commissioners	724	5	6
Contract price, and payment by the Commissioners	1,470	-	-
Contract price, and payment by the Commissioners	718	-	-
Contract price, £. 1,470; levelling and draining, £. 43. 5. 10.	1,513	5	10
Contract price, and payment by the Commissioners	1,470	-	-
Contract price, £. 1,470; extra-foundation and drain, £. 22. 5. 3.	1,492	5	3
Contract price, £. 718; extra-foundations, £. 8. 8., and contribution towards enlargement of Church, £. 150, in all	876	8	-
Contract price, £. 1,470; extra fences, and harling the Manse, £. 69. 10. 5.	1,539	10	5
Contract price, £. 1,470; extra-work in foundations, £. 25. 14. 1.	1,495	14	1
Contract price, £. 1,470; foundation of Church and Manse, £. 33. 4.	1,503	4	-
Contract price, £. 1,470; foundation, extra-work, £. 32. 10. 8.	1,502	10	8
Contract price, £. 1,470; extra-fencing, &c., £. 8. 12. 7.	1,478	12	7
Contract price, £. 1,470; inclosure of Glebe, £. 30	1,500	-	-
Contract price, and payment by the Commissioners	697	17	3
Church rebuilt by Sir P. Grant, of Rothiemurchus, at an expense of £. 395; Manse at the expense of the Commissioners	747	7	4
Contract price, £. 1,470; extra-work, and mounting a Bell, £. 16. 5.	1,486	5	-
Contract price, and payment by the Commissioners	718	-	-
Contract price, and payment by the Commissioners	1,470	-	-
Contract price, and payment by the Commissioners	1,470	-	-
Contract price, and payment by the Commissioners	1,470	-	-
Contract price, £. 1,470; for inclosing the Glebe, £. 30.	1,500	-	-
Contract price, £. 1,470; Bell, and mounting, £. 10. 15.	1,480	15	-
Contract price, £. 1,470; Bell, and mounting, £. 10. 15.	1,480	15	-
Contract price, £. 1,475. 0. 3., and allowance for extra-expense in carriage of materials, £. 24. 19. 9. (the Heritors paying £. 110. 18. 7. for the same reason)	1,500	-	-
Contract price, £. 1,452. 6.; extra-work at foundation, and Bell, £. 36. 17. 3.	1,489	3	3
Contract price, and payment by the Commissioners	1,470	-	-
Contract price, £. 1,400. 7. 9.; extra-foundation work, and Bell, £. 26. 3. 2.	1,426	10	11
The British Fishery Society gave a Manse for the Minister's residence; contract price of Church, with additional Galleries	900	-	-
Contract price, and payment by the Commissioners	1,470	-	-
Contract price, and payment by the Commissioners	1,470	-	-
Contract price, £. 1,452. 6. 2.; extra-foundation work, £. 18	1,470	6	2
Contract price, and payment by the Commissioners	1,452	6	2
Contract price, £. 1,452. 6. 2.; extra-foundation work, £. 10. 18. 6	1,463	4	8
Contract price, £. 1,452. 6. 2.; extra-foundation work, £. 21. 11. 11.	1,473	18	1
Contract price, £. 1,452. 6. 2.; extra-foundation work, £. 7. 0. 4.	1,459	6	6
The Church was repaired by the Heritor; the Manse was built at the expense of the Commissioners	718	-	-
The Church was repaired and fenced by the Heritor; the Manse was built at the expense of the Commissioners	718	-	-
The Church was repaired at the expense of the Heritor; the Manse (with a Byre) was built by the Commissioners	745	13	8
Contract price, £. 1,470; extra-expense for Byre at the Manse, £. 28. 12. 9.	1,498	12	9
A Church was rebuilt by the Heritors, at an expense of £. 673. 17. 4.; Manse at the expense of the Commissioners	718	-	-
A Church was built on a new site, by the Heritors, at an expense of £. 677. 12. 7.; the Manse (with a Byre) was built at the expense of the Commissioners, who were also put to an extra-expense of £. 43. 4. 1. by a dispute as to site, after the work was commenced	786	16	2
General Stewart, of Garth, paid £. 114 towards the renovation of the Church; the Commissioners, £. 134; Manse and Byre, £. 741. 0. 3.	875	-	3
Expense of March-Stones (Land-Marks) of sundry Glebes, Peat and Pasture Rights	38	-	-
£.	54,422	8	8

APPENDIX (N. 1.)

PROGRESS of IMPROVEMENT in the NAVIGATION of the RIVER *Clyde*.

A.D. 1755. FROM the Report of Mr. Smeaton in the year 1755, it appears that the River Clyde was at that time in a state of nature, unaided by the resources of art.

Upon sounding the river at twelve different places, between Glasgow and Renfrew, he found the two shoalest spots to be at the Hirst, a little below Glasgow, and at Point-House Ford; the former having one foot six inches, and three feet three inches;—the latter one foot three inches, and three feet eight inches at low and high water, respectively, and that the ordinary neap tides are sensible at Glasgow bridge, and rise two feet six inches at Spoydoch (where the river is eight hundred and eighty-four feet wide), at which time the navigation is open for vessels that do not draw above four feet six inches water, he recommends a lock and door to be made at Marlingford, in order to secure four feet six inches water at all times up to the Quay at Glasgow.

A.D. 1768. In the Report of J. Golborne, dated November 30, 1768, he represents the basin at Port Glasgow much filled up with mud, and recommends that two reservoirs be made for the purpose of scouring it occasionally; also, that a pier be built into the basin, which might without difficulty be converted into a wet dock. He finds the Hirst to have only one foot of water over it. The sides of the river are described as being generally much softer than the bottom, and therefore that the current has extended itself in breadth, and is wanting in depth; to remedy this defect he proposes to remove the hard gravel from the bottom, where it is shallow, and to contract the width by means of jetties. In this manner he conceives that the River Clyde may be deepened, so as to have four, or perhaps five feet at low water, up to the Broomielaw. In the opinion of Mr. Golborne, the tide coming from the sea has not a sufficient communication with the Frith of Clyde, so that if a better inlet could be given to it, he is of opinion that it would flow considerably higher at the Broomielaw.

A.D. 1769. In the Report of Mr. James Watt, dated October 20, 1769, various soundings are given (by reference to a certain fixed point, eight feet higher than the Hirst Ford). He puts great dependence upon the accuracy of Mr. Smeaton's observations, but states that all the hard fords are very uneven in the bottom, which makes it difficult to ascertain their soundings.

A.D. 1781. Mr. Golborne in his Second Report, dated 7 September 1781, expresses his satisfaction at the good state of the works, finding the spaces between many of the jetties filled up and covered with grass, to the great emolument of the proprietors, and advantage of the river; for in proportion as the tides fill up and become land, the neap tides, he says, will rise higher, and the land floods, *being more confined*, will act with greater force on the bottom, &c.; and he adds, that this will continue till the neaps bear a due proportion to the spring-tide. He finds the jetties in many places buried in silt, and advises their being raised and extended to the land. Mr. Golborne had, in September 1772, undertaken, at

an expense of £.2,300, to make Dumburk Ford six feet deep and three hundred feet wide at low water; although Smeaton, in 1758, seems to have despaired of accomplishing such an improvement; it was begun accordingly in June 1, 1773, and finished in the beginning of the November following, to the satisfaction of the magistrates, who, on sounding, did not find less than seven feet of water on it; and on sounding again with the magistrates on the 8th day of August 1781, at low water, we had the pleasure, says Mr. Golborne, to find no less than fourteen feet. Directions are given for further improvements, upon the same principle, and an estimate of £.420. 7. 6. is given for work necessary for preserving seven feet of water to the Quay at Glasgow, by the extension of five old jetties and the construction of eighteen new ones.

Mr. John Rennie makes a Report on 22d of August 1799, and observes that the depth of the river has been much increased by the measures taken since 1768, though he cannot assert positively that the section of the river is greater than it was previous to that period. A.D. 1799.

The floods are admitted to be higher, but he does not attribute this to the building of the new bridge, or to the works for the improvement of the navigation, but rather to the increase of drainage in the adjoining country. By a comparison of various sections, Mr. Rennie is of opinion, that little or no obstruction arises at high water from the works of the navigation; but he points out for removal several impediments which pen back the water; among them is the dike or wear, just below the new bridge, which might be lowered with advantage, although its entire removal would endanger the foundations of the new bridge.

Mr. Rennie states his opinion, that with these additions the works of the navigation will have rendered the river more capacious, and of course better fitted for carrying off the floods than before they were made; but notwithstanding that, the floods will never be reduced to their former state, but on the contrary will increase, as long as the lands above advance in improvement by drainage.

In the year 1806, Mr. Telford was consulted, with a view to further improvements in the Clyde navigation, and in the Port of Glasgow. A.D. 1806.

In a Report, dated 24th of May, after a thorough consideration of the subject, he gives his opinion under three heads; viz.

1. The leading or bringing up a greater quantity of tide-water.
2. The advantages to be derived from having a tracking or towing-path on a part of the river; and,
3. The forming a harbour at the Broomielaw.

1. He observes, that 'In order to obtain a greater quantity of tide-water in the upper 'part of the river, the general principle is to reduce the bed of the river to that form 'which shall afford the most direct course, oppose the fewest obstacles, and render the 'friction the least possible in regard to the section of the flowing water.'

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* Owing to the introduction of steam-tugs, towing-paths are now only used occasionally for towing rafts of timber.

Accordingly he objects to the action of jetties as productive of counter-currents, which check the velocity of the water which meets them, and as distracting the course of the river by the repeated contractions and expansions of its section, and as thereby also preventing the uniform deepening of its bed.

To remedy this, he recommends that the parallel dikes* which had been already carried into execution by Mr. Spreull should be completed. As an evidence of the improved condition of the channel, it appears that on the 14th of the previous February, Mr. Archibald Wilkie, master of the "Harmony" of Liverpool, one hundred and twenty tons burthen, then lying at the Broomielaw, had come up with ordinary spring-tides, drawing eight feet six inches of water.

2. Finding that vessels can come up as far as Renfrew with light winds, but that the plantations near to Elderslie, by taking off the winds, frequently leave them becalmed, he recommends a towing-path from Renfrew to the Broomielaw.

3. In seeking a method of providing suitable accommodation for vessels at the port of Glasgow, he rejects the plan of lengthening the present quays, and thus suffering the vessels to lie in the tideway and current of the river. The purchase of ground for this purpose would be expensive, and the arrangement inconvenient. Recourse must be had to a wet-dock, which evidently, he says, ought not to be on the south side of the river; and on the north side, there being only to choose between cutting back into the adjacent building-ground, or taking the present bed of the river, he prefers the latter expedient, as the simpler and less expensive. By frequent boring it appears, that at seventeen feet below the lowest part of the surface of the wharf at the Broomielaw, there is a waterproof
A D. 1807. stratum, and upon it a bed of gravel and soft mud, which might be excavated, and on this foundation two walls built at such a distance as to afford a quay of fifty feet in breadth between them.

Previous to commencing any new works in the present bed of the river, he directs that a part of the new channel must be formed. Mr. Telford has no apprehension that this change will cause the floods to rise any higher than usual, because the course of the river will be made more direct than before, and when the water rises to a certain height, it will flow over the quays in the same manner as it now does over the wharfs at the Broomielaw on the north, and the green ground on the south side.

He gives, as a rough estimate of the expense of these several improvements, the sum of £. 20,000.

Mr. Telford concludes his Report in these words: 'The urgency for this improvement 'is best known to those who are most connected with the shipping which frequents the 'Broomielaw; but it is evident that places of comparatively small importance have bene-'fited greatly by turning their attention seriously to the improvement of their navigation 'and harbours, and others, from neglecting to attend to these material points, have insen-'sibly lost advantages which are not easily regained.'

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* Parallel dikes are made by building a low strait wall between the points of the jetties.

In January of the following year, 1807, Mr. Rennie is consulted upon the same subject, and makes a report, under the disadvantage of not having had an opportunity of examining the localities, owing to a press of business, and to the swelled state of the river. He had previously advised that low rubble-walls should be built from jetty to jetty, in order to prevent the accumulation of shoals in the intermediate portions of the channel, and that the substance of these shoals should be taken out and deposited behind the proposed walls, so as to make land. He now finds this plan carried into execution, with the best results, and urges its continuance. He strongly approves of the proposal for a towing-path. A.D. 1807.

Of the two methods for improving the accommodation for vessels, he judges that of lengthening the quay to be the more simple and economical, but that of forming a wet dock to be the only complete, effectual and convenient arrangement. In this and a subsequent report, he points out several sites as suitable for the formation of a wet-dock, and specifies their respective claims to preference; but, contrary to his recommendation, it appears that the Lord Provost and Magistrates of Glasgow decided upon the situation at the Broomielaw, as most desirable upon the whole for this purpose.

On the 24th of December 1807, Mr. Rennie reports that he had made numerous soundings in the river, finding generally about a foot less water between the jetties opposite the ends of them. Owing to the narrowness and crookedness of the channel, he considers the navigation by no means safe and good, and pronounces the principle upon which the improvements have been carried on to be very deficient, and recommends as a remedy that the low connecting walls should be adopted throughout the whole length of the river. He gives the widths to which the river should be reduced at a great number of places. The greatest width proposed is six hundred and ninety-six feet, and the least one hundred and thirty-five feet. At this period there were not less than one hundred and ten jetties laid down.

Mr. Rennie is of opinion that the lowering of the Weir would be of greater advantage in carrying away the flood-water speedily than any other work that could be devised, unless the waterway of the old bridge were to be enlarged, which he finds to be less than the waterway of the new bridge. In calculating this, he observes that no one has hitherto made allowance for the *oblique* direction of the new bridge to the current of the river, by which the free passage is much obstructed. He concludes by urging the lowering of the weir one foot or eighteen inches, combined with the adoption of a wet-dock.

By a Report of Mr. Rennie's, dated two days after the above, it appears that several objections were raised by the municipal authorities to the plan proposed by Mr. Rennie for a wet-dock, owing to their apprehension of its obstructing the passage of the land-floods.

These objections are refuted by Mr. Rennie, and, at the same time, another plan is proposed by him more adapted to the circumstances, at a reduced estimate of £.32,378; but it appears in his subsequent report of February, 1809, that this sum exceeded the wishes of the city, and consequently Mr. Rennie furnishes a less expensive plan by proposing an excavation on the south side, with a quay wall of eleven hundred and fifty feet long. The estimate, accompanied by a specification, amounts to £. 21,500. A.D. 1809.

A.D. 1819. On 29th November 1819, Mr. Telford furnishes a plan for a wet dock, in pursuance of
A.D. 1821. instructions, and upon data transmitted to him; and again on the 20th December 1821, he recommends as a temporary and economical expedient for getting additional berthings and wharfage, that the Broomielaw quay should be extended; but neither of these plans were then carried into execution.

A.D. 1824. On September 1, 1824, Mr. Whidbey is consulted generally upon the subject of this navigation; he states in answer his regret that so much has been done heretofore to ruin the river Clyde, by reducing its channel to about one-third of what it had been originally in width, viz. from one thousand four hundred feet to four hundred and forty; that the tide is thus prevented from flowing over the space it usually did, whereby the quantity of backwater and its scouring effect is greatly diminished. He apprehends that in consequence bars will grow up at the entrance of the Clyde, although he has not the means of ascertaining any such actual tendency; he advises that a stop be put to all the proceedings then going on, and regrets that every existing work cannot now be undone. Understanding that there is a shoal extending across the river at the Cart, seven miles below Glasgow, with only four feet water on it at low-water spring-tides, and consequently fourteen feet at high water, he recommends the use of the dredging machine, as the only means left for preserving the navigation of the river.

In November 1824, Mr. John Clark reports upon the visible effect which has resulted from the adoption of parallel dikes in deepening the river; in 1806 the largest vessels in the Liverpool and Bristol trade drew eight feet six inches water, whereas now he finds them drawing eleven feet, and with less detention than the former vessels previously; and he attributes this result entirely to the extension of the dikes, and also asserts that the new dredging apparatus has raised more stuff since set to work than has been taken out of the river for the last twenty years. He recommends the buying up of a fishing station at Lungoch bay, which has hitherto prevented the connection of the parallel dikes in that place.

A.D. 1826. He recommends a portion of ground on the south side of the river to be appropriated for a harbour; and in March 1826, Mr. Telford furnishes instructions for laying out this site, and proposes, with a view to expedition and economy, that the intended new wharfs should be constructed with timber, after the manner of the late extension on the north side of the river.

A.D. 1832. Mr. John Clark, who had been bred a millwright, and for many years had the superintendence of the workmen employed in dredging, deepening, building wharfs, parallel dikes, and in short all the works which were carried on under Mr. Spreull, with the occasional advice of some of the engineers previously referred to, having fallen into bad health, the trustees, with the approbation of Mr. Telford, engaged Mr. Charles Atherton as resident engineer, Mr. Clark still continuing to superintend the dredging department, having under his charge three powerful dredging machines, besides three diving bells, and numerous craft for conveying the stuff from these machines. In compliance with Mr. Telford's report already noticed, the trustees replaced several portions of the north quay wall which had previously been constructed of timber, with a substantial stone wharf, bringing

the whole to a uniform level, which, with the addition of three hundred feet now in progress, makes the north quay of the Broomielaw harbour three thousand six hundred and thirty feet in length, all of which is well paved, and on which there is a fine range of sheds two thousand one hundred and fifty-five feet in length, having an area of fifty-eight thousand one hundred and eighty-five superficial feet.

The wooden wharf on the south side, which had been constructed from an injudicious economy on the part of the trustees, was found to render the harbour too narrow; Mr. Atherton therefore prepared a plan for extending the wharf on the south side, as 1833.
approved of by Mr. Telford, from the new Glasgow bridge then in progress, so as to increase the width of the Broomielaw harbour from an average of two hundred and sixty-seven to three hundred and seventy-six feet, for a length of one thousand feet. This wall was built of stone, founded on piles at such a depth as to admit of the bottom being excavated, so as to give a depth of twenty feet in spring-tides, and was covered with a coping of Aberdeen granite.

Mr. Atherton having resigned his situation in 1834, Mr. David Lagan, formerly resident 1834.
engineer under Mr. Rennie at Donaghadee, was appointed by the trustees; in conjunction with Mr. William Kyle, an eminent surveyor, he was directed to make a new survey of the river, together with accurate sections of the river from the Broomielaw harbour to port Glasgow, and also borings of those parts which had hitherto been found most difficult to deepen. This work having been performed by the respective parties in a very masterly manner, Mr. Lagan submitted his report to the trustees in October 1835, accompanied with 1835.
the plans and sections, on which were laid down the various improvements which he had to propose; but Mr. Telford, who had long been occasionally consulted by the trustees, having died in 1834, they deemed it advisable to consult Mr. Walker, who was accordingly 'requested to visit Glasgow for the purpose of inspecting the river Clyde and its survey, 'in connection with the plans of Mr. Lagan, and to report his opinion fully thereon,' and also 'to consider generally as to the best means of promoting the trade of Glasgow.'

In Mr. Walker's Report, of date the 11th July 1836, he states,—'In compliance with 'the above, I visited Glasgow in October last, when I found an excellent survey of the river 'and harbour by Mr. Kyle, upon which Mr. Lagan had laid down lines for a proposed 'enlargement, deepening and straitening, and also for docks, and had fully reported on 'the subject. On that occasion I accompanied Mr. Lagan and Mr. Gibb down the river, 'to the extent of the proposed improvements, and likewise up as far as Dalmarnoch 'Bridge, about half a mile above Ruthington Quay. I also examined and advised as to 'the sites that appeared to me to have the greatest advantages; considered the plans 'prepared by Mr. Lagan; suggested such alterations as I deemed advisable, and settled 'with him the dock and river plans, to be deposited preparatory to the application to 'Parliament.'

After stating that he again visited Glasgow in the middle of January, Mr. Walker proceeds,—'Mr. Lagan's report and plans, giving a minute detail of the present and proposed 'state of the Clyde, having been printed, supersedes the necessity of repetition by me. 'His river lines appear to be laid down judiciously; I have proposed some, but no very

'material alterations in them. The design is sufficiently extensive as a maximum, which 'is the safe course in applying to Parliament, if the funds will justify it. The plan pro- 'poses a width of three hundred feet from Broomielaw to above Renfrew Ferry, where, to 'the river Cart, it widens to from four hundred to four hundred and thirty feet; thence to 'Dalmuir Quay, four hundred and forty; to Rushleigh Quarry, five hundred; to Erskine 'Ferry, five hundred and forty; to Donald's Quay, five hundred and ninety; to Bowling 'Bay, six hundred, and to Dineglass Casle, six hundred and thirty; the depth being 'almost uniformly twenty feet, with high water at neap tides.

'In the execution of this great work, it is, however, not unlikely that some partial 'alterations from the plan now laid down may be expedient. The chief one I have at 'present recommended is at the lower end, or opening of the estuary near Dumbarton, 'with a view of preventing diminution of tidal water, which might be the effect of carrying 'the side banks above the tide; and therefore I propose still to confine the current in the 'proper channel by means of banks, but these not higher than half this level, and to 'have beacons, of sufficient height, placed at intervals as guides when the water is over 'the banks.

'As a general question, there can, I think, be no doubt as to the proposed enlarge- 'ment being beneficial, not only by giving much additional facility for shipping, but 'by improving the great drain of the country, and so preventing the river from overflow- 'ing the low lands near it, and (which I take to be very important) by lessening, or 'entirely doing away with the flooding of the low parts of Glasgow, and the quays at 'the Broomielaw.

'The sides of the river are proposed to be paved with rough rubble-stone dikes, as 'described by Mr. Lagan, in his Report. There seemed an idea with some members 'of the trust that deepening would be sufficient, and that the stone facing, which is 'expensive, is unnecessary. It would be so if the soil composing the sides were of so 'firm a nature as not to be moved by the current, and if thus the proper width could be 'preserved; but this is not the case, and therefore any attempt to narrow or deepen, 'without securing the sides with heavy material, would be useless. The land-floods would 'undermine the banks, which would fall in, the river would widen, and be irregular and 'shifting, and shoals would form as before; whereas by confining the sides by a material 'which is more difficult to move, the soil of the bottom gives way to the increased 'velocity, which is the natural effect of the narrowing, from the water working to obtain 'in depth what it finds it cannot in width. I am aware that a very different opinion 'has been expressed by the late Mr. Whidbey, a highly respectable authority in many 'points, but not superior to Golburne, Rennie and Telford, who all thought differently. 'Mr. Whidbey's opinion appears to have been founded upon the idea, that the Clyde up to 'Glasgow depends chiefly upon the tide: I think otherwise; and that the sectional area 'of the river, nearly as far down as dredging is wanted, is caused by, or is the effect of, 'the land-floods, much more than of the tide-water. I do not say that the latter is 'useless, or that it ought not to be encouraged; but only that, comparatively, it is of 'less consequence for scour than the land-waters. I believe that the velocity of an 'ebbing tide may be taken at a mile and a half an hour near the harbour. Now the

'fresh I saw ran four miles and a half per hour, and at that time it had subsided two 'feet from the height at which it had been during the night. Evidently, such a scour 'must have a much greater effect than the tidal current of a third the velocity, and if 'this be not sufficient proof of the soundness of the plans that have been pursued, it is 'not necessary to go to other rivers for illustration, although there are many; but only 'to compare the Clyde as it is, with the Clyde as it was before the operations began, 'when the tide had its full range of width. Lower down the river, near Dumbarton, where 'the river is wider, the land-floods become unimportant, as compared with the tides; and 'therefore it is that the tide ought to be the chief object of care; and that I have 'recommended the dikes being kept down, so as to prevent as much as possible a 'diminution of the tidal water.

'The proposed widening up to Glasgow will increase the tidal receptacle or reservoir, 'and therefore tend to improve all the lower part of the river that depends upon the tide 'for its depth.'

With regard to the wet docks proposed, Mr. Walker says, 'The subject next in 'importance is docks; without which there might, notwithstanding the addition now 'making to the width of the harbour, be the objection, that, providing great depths for 'heavy ships is doing but half the work, if they are to be subject to ground when the 'tide retires; and I agree with Mr. Lagan, that the tendency of straitening and 'cleansing the river will be rather to reduce the low-water level at the Broomielaw.

'Three sites have been proposed for docks; viz. two on the north, and one on the south 'side; of these, I think that on the south side, on the whole, the most desirable to com- 'mence with: it extends from New Bridge-street to Mr. Tod's factory, and is bounded on 'the south by King-street, being a quadrangle, of which the entirely vacant ground, called 'Windmill Croft, forms about a half. This will give room for two docks, of (together) 'fifteen acres, or accommodation for one hundred and fifty ships, with quays all round, 'and a space for Govan and Pollock railway between. The entrance lock is proposed to 'be two hundred feet long by sixty feet wide, so as to admit the largest steamers; the 'depth to be twenty feet at high water of neap tides.'

With the view of carrying into effect the improvements in the river and harbour recom-
mended by Mr. Walker and Mr. Lagan, the trustees applied to Parliament in 1836 for an 1836.
Act empowering them to borrow money for this purpose, and to construct a wet-dock or docks, and charge rates for dockage on the vessels. They stated their case in support of the Bill as follows:

'The Magistrates and Council of Glasgow, about the year 1770, commenced, by means 'of the corporation funds of the city, what was then conceived to be the hazardous 'undertaking of deepening and improving the navigation of the Clyde, and enlarging the 'harbour of Glasgow. The river was then in many places fordable at low water by men 'and horses; and at high water of spring tides did not exceed four feet six inches in 'depth. By the successful operations carried on by the trustees, the river is now, in the 'words of Mr. Walker, "at the Broomielaw (or harbour of Glasgow), from seven to eight '"feet at low water, while the lift of a neap tide at Glasgow Bridge, which was only

' " sensible in 1755, is four feet, and of a spring tide seven or eight feet, making twelve ' " feet deep at high water of a neap, and fifteen of a spring tide." '

' The importance of these operations to the trade of the country will best appear by the ' following progressive and corresponding increase in the revenues of the trust:—viz.,

The TONNAGE and HARBOUR DUTIES for the year—

' 1771 were - - - -	£. 1,071	1828 were - - - -	£. 17,669
' 1791 „ - - - -	2,145	1830 „ - - - -	20,296
' 1804 „ - - - -	4,760	1832 „ - - - -	22,496
' 1815 „ - - - -	5,960	1834 „ - - - -	22,859
' 1825 „ - - - -	8,408	1835 „ - - - -	31,900
1826 „ when 33 per cent. were added to the rates -	16,200	And this year, 1836, it is expected that the rates and duties will produce - - - -	35,000

' The actual produce for 1836 was - - - - - - £. 35,612.

' It is obvious that this unprecedented increase of traffic must create a great demand for ' additional harbour accommodation and facilities of navigation. A harbour of sufficient ' capacity to contain shipping paying duties to the amount of £. 8,404 as in 1825, or ' £. 16,200 as in 1826, cannot accommodate shipping yielding a revenue of £. 31,900 as ' in 1835, or £. 35,000 as in 1836. The same observation applies to the width of the ' river, in many places not greatly exceeding one hundred and sixty feet. Impressed with ' the urgent necessity for adding to the harbour accommodation, and to the width of the ' river, the trustees consulted engineers of eminence upon the best means of accomplishing ' these purposes; and the object of the present Bill is to obtain powers to carry into ' effect the plans of Mr. Walker and Mr. Lagan with that view.'

In a statement addressed, the 22d of January 1835, by Mr. W. Johnstone, to the trustees on the river Clyde, it is fully shown that the accommodation at the Broomielaw is quite inadequate to the great and increasing commerce of Glasgow. Vessels newly arrived are not uncommonly detained five or six days for want of an inside quay berth, and every vessel is obliged to be shifted, on an average, at least five or six times. The consequent demurrage is expensive and injurious to merchants and ship-owners, while the cost on the other hand, of discharging a cargo in an outside berth, is often double of the amount of the river-dues, payable by the vessel—even this alternative being impracticable to the coal trade. Vessels are often forced to lie in tiers, of five, six, and sometimes even seven and eight deep. The number of vessels coming to the Broomielaw is more than ever on the increase; the arrivals during the previous year having been five thousand five hundred and sixty-three, of which one hundred and twenty-five were from foreign ports, a proportion that promises to be much augmented.

The number of steamers plying during the summer of 1834 to and from this port was fifty-four, making eight thousand and seventy-six arrivals in the course of the season, while twenty new steamers are said to be in preparation for the next season. In the mean time there is berth-room only for ten, whereas it is required for sixteen. It appears that in 1834, Greenock and Port Glasgow made but a small increase in the number of large

vessels, compared with that gained in 1833, while the increase gained at Glasgow was as follows:—

	1833.	1834.	Increase.
Of Vessels - - 100 to 150 tons -	226	264	38
Ditto - - - 150 to 200 „ - -	19	48	29
Ditto - - - 200 to 250 „ - -	2	14	12
Ditto - - - 250 to 300 „ - -	2	6	4

From the return of the draught of water of the whole number of vessels in Lloyd's books of 1833, it may be seen that the river, at the present depth of fifteen feet at spring-tide, is capable of admitting to the Broomielaw *four-fifths in number of vessels of the whole registered British tonnage*; and one foot more in depth would suffice to admit more than a half of the remainder. The expediency, therefore, of providing accommodation on a liberal scale must be obvious.

Although the need of further accommodation for the shipping, and the benefits that would be derived from the proposed improvements in the river, were clearly proved to the satisfaction of the committee, the trustees did not succeed in obtaining an Act of Parliament enabling them to carry these works into execution. In consequence of the opposition of various bodies, whose interests were adverse to the proposed measures, and of others, founded on objections to the constitution of the river trust, the Bill was withdrawn.

Since that time, however, the trustees have continued to carry on the operations for improving the navigation throughout the whole extent of the river, as well as for extending the wharf on the south side, which now measures not less than two thousand four hundred feet in length, from the Glasgow bridge downwards, which, together with the berthage on the north side, makes an extent of quay-berthage of upwards of six thousand feet in length. Nothing, however, has hitherto been done towards forming a wet dock.

The subjoined statement shews the comparative increase of steam-navigation and of sailing vessels up the port of Glasgow, from 1828 to 1836, inclusive.

YEARS.	SAILING VESSELS.		STEAM VESSELS.		Total Arrivals.	Total Tonnage.
	Number of Arrivals.	Tonnage.	Number of Arrivals.	Tonnage.		
1828 - -	4,405	214,315	7,000	481,946	11,405	696,261
1831 - -	4,005	186,576	7,576	545,751	11,581	732,327
1834 - -	4,527	211,464	8,267	616,050	12,794	827,573
1836 - -	4,799	244,610	9,052	718,044	13,851	962,654

APPENDIX (N. 2.)

NARRATIVE of the ORIGIN and PROGRESS of STEAM NAVIGATION.

ALTHOUGH numerous accounts have been given, in a detached form, of the rise and progress of steam navigation, it is believed that hitherto no conjoined statement has been drawn up of the various schemes which have been laid before the public for carrying this admirable invention into practice. The object, therefore, of this paper is to bring under review the different accounts of the progress of navigating vessels by steam power, in the order in which the original projectors had brought them before the public, so that the history may easily be continued hereafter, by adding whatever, in the course of time, may seem useful or instructive.

The first projectors of steam-boats appear to have confined their views entirely to towing-vessels for carrying ships out of or into harbours, in rivers or otherwise, in adverse winds. The first boat of this description on record was proposed by Mr. Jonathan Hulls (of Exeter), for which he took out a patent, which was signed on the 21st of December 1736. The specification sets out with a description of the boat and machinery, accompanied with a plate, representing the boat in the act of towing a ship of war, having the tow-rope fixed immediately under the foretop. The towing-vessel is represented with two distinct paddle-wheels, projecting a considerable distance beyond the stern, and suspended from two projecting beams. The funnel is placed nearly in the middle of the boat, and the engine bearing towards the stern. It does not appear, from any subsequent accounts, that Mr. Hulls was able to reduce his scheme to practice. In addition to the specification, he published in London, in 1737, a pamphlet, containing a more enlarged account of his scheme, which, it is believed, is now very rare. Upon the whole, although Mr. Hulls is entitled, so far as known, to priority in having brought before the public the first scheme for navigating vessels by the aid of steam, subsequent experience has certainly shewn, that the manner in which he proposed to work his paddles would have been altogether unfit for the purposes intended, even of towing vessels into or out of a harbour, unless when the weather was perfectly calm, and no swell in the sea. The scheme, however, seems in a few years to have been entirely forgotten.

The next effort to propel vessels by machinery was taken up by Mr. Patrick Miller, of Dalswinton, a landed proprietor in Dumfries-shire, who had devoted much of his time to mechanical pursuits. About the year 1785, he began a series of experiments for applying paddle-wheels to vessels, with a view of towing or extricating vessels when beset with adverse winds, or placed in dangerous situations. But at this period, his ideas of the propelling power were confined to machinery worked by manual labour.

About this time Mr. Miller engaged Mr. James Taylor, then about 27 years of age, as tutor to his son. Mr. Taylor was a man of very general knowledge, and passionately fond of mechanical pursuits. He entered warmly into Mr. Miller's views, and under their joint superintendence a sort of twin vessel, of about sixty feet in length, was constructed

with intermediate paddles, which were moved by men working a capstan. The first experiment with this boat was tried against a custom-house wherry, which it easily distanced; but although this gave a convincing proof of the advantage of paddles, it was observed that the men were very soon exhausted by their labours at the capstan, and it was evident that unless some superior power was obtained, the invention of paddles would be of no avail. Mr. Taylor having communicated his thoughts to Mr. Miller, that gentleman stated, that this view of the question was entirely in accordance with his own, and desired him to apply himself to the consideration of all the mechanical powers which were most likely to effect the desired object. Accordingly it at last occurred to Mr. Taylor that the application of the steam-engine might be practicable; Mr. Miller admitted the efficiency of the power, but doubted the practicability of its application. Mr. Taylor, however, persevered, and prepared drawings of his proposed scheme for Mr. Miller's consideration, with which the latter was, in some degree, satisfied, but not fully convinced. However, as it was arranged that Mr. Miller's sons were to enter the University of Edinburgh early in November 1787, under the charge of Mr. Taylor, Mr. Miller authorized Mr. Taylor to get an engine constructed at Edinburgh for the purpose. The latter accordingly recommended to Mr. Miller to employ an ingenious young engineer of the name of Symington, who was then residing in Edinburgh, for his improvement in mechanics, to make an engine on his own plan, so that the experiment might be tried during the ensuing summer in a lake at Dalswinton.

The construction of the engine, having occupied more time than was at first anticipated, was not completed at the close of the University session. Mr. Taylor, therefore, remained several months longer in town to superintend its completion. When all was ready, he proceeded, along with Mr. Symington, to Dalswinton, where, on the 14th October 1788, the experiment was made on a twin boat, in presence of Mr. Miller and a considerable number of spectators. The engine had only a four-inch cylinder, which was placed in a frame on the deck. The experiment was successful, even beyond the most sanguine expectations of any of the parties concerned. The vessel was moved at the rate of five miles an hour, and no inconvenience was found in connecting the engine with the paddle-wheel. During the few ensuing days, the experiment was repeated with perfect success, so that the invention became a subject of great local notoriety.

Mr. Miller now intended to secure his own and Mr. Taylor's joint invention by a patent; but before doing so, it was deemed expedient to make an experiment with a vessel and engine, approaching nearer to a size that might be applied to useful purposes. Mr. Taylor, therefore, by the instructions of Mr. Miller, proceeded with Mr. Symington to the Carron Foundry, and there, during the summer of 1789, they fitted up a suitable vessel with an engine, having a cylinder of eighteen inches diameter, which in the month of November was placed in the Forth and Clyde Canal, and in presence of the Carron committee of management and others interested, the machine was set agoing. The paddles were at first found too weak, but these having been reconstructed, the vessel was started on the 26th December, when an easy and uninterrupted speed was accomplished, at the rate of seven miles an hour; this, then, was really and truly the first practical application of steam power for propelling vessels, of which we have any account.

The outline of the scheme was now considered, in a great measure, perfect, in as far as regarded the objects of inland navigation; but when Mr. Miller, who had hitherto contributed the whole expense, found that it much exceeded his expectations, he blamed Mr. Taylor and Symington for their extravagance, and some mutual recrimination took place. Mr. Miller had made application to several governments, as well as our own, for their patronage in bringing forward the invention; but it is understood that he received information through a private channel, that owing to his political opinions, which were at variance with those in power, he was not likely to receive any encouragement; he, therefore, gave his coadjutors for answer, that he would take a year or two to consider of it, before he entered further into the business. In the interim, having engaged his ardent mind in some important agricultural experiments, no argument of Mr. Taylor's could prevail on Mr. Miller to resume the subject, and Mr. Taylor, being entirely without the means of prosecuting the business on his own account, made application to some friends on the continent, which only led to fruitless inquiries. From the indifference, therefore, of Mr. Miller, and the direction of the public attention to the war, which soon after commenced, and the situation of Mr. Taylor, a comparatively obscure individual, residing in an inland part of the country, (superintending the working of a coal and lime work in Dumfries-shire, with only the means of supplying his daily wants, and of course unable of himself to do any thing), the project remained for several years in abeyance.

Mr. Symington, who had commenced business for himself in Falkirk, now came to the resolution of prosecuting the design of steam navigation, in which he had already taken such an active part. He applied to Lord Dundas, then governor of the Firth and Clyde Canal Company, who employed him to fit up an experimental boat for the purpose of towing vessels on the canal. It was found, however, that the motion of the wheels was very injurious to the banks, and the vessel was laid up and allowed to fall to pieces.

Some time after this, Mr. Fulton from the United States of America, accompanied by Mr. Henry Bell, from Glasgow, (who, as a native of Torpichen, a parish between Linlithgow and Falkirk on the south, had no doubt heard of the previous attempts to navigate vessels by the aid of steam), waited on Mr. Symington, and accompanied him on an inspection of the boat he had fitted up for the Forth and Clyde canal. The consequence was, that during the year 1807, Mr. Fulton launched a steam-boat for the conveyance of passengers on the river Hudson, in the United States; and during the year 1812, Mr. Henry Bell launched another in the river Clyde, for conveying passengers and luggage or light goods.

Before entering, however, on the history of Mr. Bell's first attempt, it may be right to say a few words by way of conclusion to Mr. Miller and Mr. Taylor's scheme. There can be no doubt that these gentlemen had overcome all the primary difficulties of the invention. It is true that their views never, it would appear, went farther than that of towing other vessels, whereas Mr. Fulton and Mr. Bell at once constructed the same boat which carried the machinery, with suitable accommodation, for the purpose of conveying, in the first instance, passengers and luggage; yet it is equally clear that these latter gentlemen were indebted for the idea to the previous inventions actually reduced to practice by Mr. Miller and Mr. Taylor. Therefore the inference is, that if the former gentleman had been

inclined, and the latter able, to follow out his scheme, they would not have been anticipated in forwarding a measure which has proved, or promises to be, of the greatest importance to every quarter of the globe. It is stated that Mr. Taylor by no means sat calmly down when he learned what had been done by Mr. Fulton and Mr. Bell; but repeatedly urged Mr. Miller to further exertions, though without success. At last, in 1824, when the vast importance of steam navigation had become in a great measure established, he was urged by his friends to state his claim to Government, and he accordingly drew up a memorial, addressed to Sir Henry Parnell, Bart., then chairman of a Select Committee of the House of Commons on Steam Navigation, but it had no effect. Since his death, however, it is believed that a pension of £. 50 a year has been granted to his widow. This indefatigable individual, bowed down by infirmities, and the fruit of a long life of disappointments, died on the 18th September 1825, aged 68.

Mr. Henry Bell, as has already been noticed, was born in the parish of Torpichen, and county of Linlithgow, in 1767; he died at Helensburgh, in the county of Dumbarton, on the 14th November 1830. He was originally bred a house carpenter, and for some years carried on extensively the business of architect, builder and cabinet-maker, in Glasgow; but being of a speculative turn of mind, and having a strong natural genius and bent for mechanics, he began, about the year 1806, to construct an extensive range of hot and cold baths at Helensburgh, on the right bank of the river Clyde, which was then a place of comparative obscurity, but has now a population of about eighteen hundred. Here Mr. Bell constructed a steam-engine for pumping water, and heating his baths, heating a conservatory, &c.; but observing that the then imperfect mode of conveying passengers by small sailing-boats from Glasgow by the Clyde was exceedingly tedious and uncomfortable, the distance by turnpike being about twenty-three miles, he turned his attention (suggested no doubt by what he had previously seen on the Forth and Clyde Canal) to propelling a passage-boat by steam; and having constructed an engine with a twelve-inch cylinder at the baths, where he had workshops for this purpose, he employed Mr. John Wood, an eminent ship-builder in Port Glasgow, to build a boat for carrying the same. This boat, which he named the Comet, was forty feet keel, and ten feet six inches beam, with a paddle-box beyond on each side. This being the first steam-vessel offered for the service of the public in Europe for the conveyance of passengers, it may not be out of place here to insert a copy of the first advertisement.

'STEAM PASSAGE BOAT, COMET,

'Between *Glasgow, Greenock* and *Helensburgh,* for Passengers only.

'The subscriber having at much expense fitted up a handsome vessel to ply upon the 'river Clyde, between Glasgow and Greenock, to sail by the power of wind, air and steam, 'he intends that the vessel shall leave the Broomielaw on Tuesdays, Thursdays and 'Saturdays, about mid-day, or at such hour thereafter as may answer from the state of 'the tide; and to leave Greenock on Mondays, Wednesdays and Fridays, in the morning, 'to suit the tides.

'The elegance, safety and speed of this vessel require only to be proved to meet the 'approbation of the public, and the proprietor is determined to do every thing in his power 'to merit public encouragement. The terms are for the present fixed at 4*s.* for the best 'cabin, and 3*s.* for the second, but beyond these rates nothing is to be allowed to stewards 'or any person employed about the vessel. The subscriber continues his establishment at 'the baths at Helensburgh, the same as for years past, and a vessel will be in readiness to 'convey passengers in the Comet from Greenock to Helensburgh.

'Passengers by the Comet will receive information of the hours of sailing, by applying 'at Mr. Houston's Office, Broomielaw, or at Mr. Thomas Blackney's, East Quay-head, 'Greenock.

(signed) '*Henry Bell.*'

'Helensburgh Baths, 5th August 1812.'

As might have been expected from a first effort, the power of the engine was found not adequate to the size of the boat, and the speed did not exceed five miles an hour; but by subsequent improvements in the same engine, Mr. Bell succeeded in obtaining a speed, under favourable circumstances, of seven miles an hour.

The application of steam, however, as a propelling power, not having, as has been shown, been first put in practice by Mr. Bell, he could not cover his outlay by patent; and it having soon become apparent that the scheme was likely to succeed, others were stimulated to embark in the business, and attempts were even made to deprive Mr. Bell of the merit of several important improvements which he had been enabled to effect. As it soon appeared that steam navigation was rising in importance, individuals and companies having the command of capital were shortly enabled to outstrip Mr. Bell, by the construction of superior boats with greater power. He had no sooner established the trade in one place than he was driven to another; and after struggling for many years, it is believed without having realized any profit, he at last retired on a pension bestowed on him by the trustees for the river Clyde, which his widow, it is understood, still enjoys.

The rapid progress which steam navigation has made in Europe, as well as in America, is so well known to the public, that it is not intended in this brief sketch to trace it progressively; but it may be proper to notice, that it was soon found by those who immediately followed Mr. Bell, that the boats then in use were very deficient in strength, as well as in steam power, and that in order to navigate the open sea, very important additions in both cases would have to be made. But although both of these have been accomplished, and steam ships are now constructed not only of enormous dimensions, and with engines of a corresponding power, which have been found capable of navigating in all weathers, and, in short, keeping their times almost with the certainty of a mail coach, yet, with the exception of superior power, and improved boilers and condensers, the general principles of the arrangement of the machines made by Mr. Bell amongst his first efforts have been but little varied.

But when the dimensions of the first engine cylinders adopted are compared with those of the present day, the difference appears truly wonderful.

14 Oct. 1788:	The diameter of the first cylinder used by Messrs. Miller and Taylor on the lake at Dalswinton -	4 inches.
26 Dec. 1789:	That used by the same gentlemen on the Forth and Clyde Canal - - - - - - - -	18 inches.
1801:	That made by Mr. Symington for towing on the Forth and Clyde Canal - - - - - - - -	22 inches.
1812:	Cylinder of Mr. Henry Bell's first Comet, used for passengers, forty feet keel, ten feet six inches beam -	12 inches.
1837:	The great Western and Victoria steam ships, for the trade between London and New York, the former built at Bristol, tonnage one thousand three hundred tons, two cylinders, two hundred horse power each, diameter - - - - - - - - -	73 ½ inches each.
	Victoria, built in London, length in the water line	230 feet.
	Beam - - - - - - - - -	40 "
	Depth of hold - - - - - - -	28 "
	Breadth over paddle-boxes - - - - -	69 "
	Tonnage, one thousand eight hundred tons.	

Two cylinders, each seventy-eight inches diameter, two hundred and thirty horse power each, paddle wheels thirty feet diameter; thus giving to the Victoria's cylinders an area of 9556·7572 inches; whereas Bell's first Comet had only one cylinder, with an area of 113·0976 inches, or, say the cylinders of the Victoria are no less than eighty-four and a half times greater than that of Bell's Comet.

J. W. Gibb.

Appendix (N. 3.)

GLASGOW BRIDGE SPECIFICATION.

Site.

The Glasgow bridge is to be built across the river Clyde, at the east end of the Broomielaw harbour, its longitudinal centre line ranging with the centre line of Jamaica-street and Bridge-street.

General Description and Dimensions.

The bridge is to consist of seven arches, of the form and dimensions shown by the accompanying drawings, being five in number, all signed by Thomas Telford, and dated London, 6th November 1832.

The arches are to be circular segments, of which the span of the centre arch is to be fifty-eight feet six inches, and rise ten feet nine inches. The span of each arch adjacent to centre arch to be fifty-seven feet nine inches, and rise ten feet six inches. The span of each arch adjacent to abutment arches fifty-five feet six inches, and rise nine feet eight inches. The span of each of the abutment arches fifty-two feet, and rise eight feet three inches. By which proportions the radius of curvature of each of the seven arches will be forty-five feet, so that in the erection of the bridge, one centre may serve for the construction of different arches, and no more than three centres will be required for the whole. The piers are to be of the respective thicknesses in the dado, of nine feet, eight feet six inches, and eight feet, and the centre of the newel at the termination of the wing-walls to be sixty feet from the faces of the abutments, making the entire length of the bridge from centre to centre of newels five hundred and sixty feet, and between the faces of the abutments four hundred and forty feet, of which three hundred and eighty-nine feet is open waterway.

The width across the soffit of the arches is to be fifty-two feet, the width within the dado of the parapets to be fifty feet, of which thirty-two feet in the middle is to be a driving way, and nine feet on each side a footpath.

Approach Banking.—Approach Levels.

The centre of Jamaica-street, at the crossing from Great Clyde-street to Broomielaw-street, is to be raised two feet two inches above its present level, and the centre of Bridge-street, at the crossing from Carlton-place to Clyde-place, is to be raised six inches, which will be just sufficient to prevent the streets being overflooded as heretofore, and the carriage-way over the bridge will form a uniform curve, rising at the centre of the bridge eight feet above the aforesaid points; the horizontal distance being three hundred and fifty feet, giving the mean slope of the carriage-way one in forty-four.

Sites of Cofferdams to be cleared of Stones, and upper Surface Levels of Water not to be affected.

The mode of proceeding with the erection of the bridge to be as follows:—

Cofferdams, as hereinafter specified, are to be constructed for getting in the foundations of each of the abutments and piers. The space which each of these dams will occupy is to be cleared of stones, and excavated to the depth of four feet six inches below the level of the weir, and in doing this, a temporary dam must be constructed, as shown in the drawing, or other measures must be taken, to the satisfaction of the resident engineer, by which the surface level of the water above the bridge may be in no respect altered by the bridge operations.

Each cofferdam is to be formed of two rows of Dantzic or Memel timber, or sound American red pine, driven parallel to each other, at the distance of five feet apart, measuring from centre to centre, and enclosing a sufficient space of ground for getting in

the foundations, leaving three feet of clear space all round between the foundation course of masonry and the inside of the dam.

Cofferdam.—General Dimensions and Description.

In order that the piles constituting each row of the dam may be wedged closely together, gauge-piles of twelve inches by twelve inches scantling are first to be driven in each row, at the distance of six feet apart, measuring from centre to centre, to which walings, as hereinafter specified, are to be fixed. The intermediate or sheeting-piles between the gauge-piles are to be of twelve inches by six inches scantling, but the last pile driven in each bay, or space between the main gauge-piles, is to be of sufficient width to force the other piles to joint closely with each other.

Dam Gauge Piles.—Benchmark for regulating the Levels.

The gauge-piles for each row are to be not less than twelve inches square, and thirty feet long. These are to be shod with wrought-iron shoes, of not less than twelve pounds each, to be hooped with best scrap iron, not less than three inches broad, and five-eighths of an inch thick, and driven down until the point of each pile is thirty-three feet below the level of the top of the quoin coping-stone of the north quay wall, west of the stair, at the east end of the Broomielaw harbour; which fixed benchmark will be pointed out by the resident engineer, and is ten feet four and a half inches below the level of the upper edge of the brass plate fixed against the wall of the Council Chambers of Glasgow, to indicate the height of flood of 12th March 1782.

Dam Walings.

The gauge-piles having been driven perpendicular, and so as to range truly with each other, double walings are to be fixed to connect the piles firmly together, and guide down the sheeting-piles. Each of these double waling pieces is to be twelve inches by nine inches scantling, to be placed horizontally, one on each side of the heads of each row of gauge-piles, and to be bolted together with two three-fourths of an inch screw-bolts passing through the head of every gauge-pile. The walings are to be checked three inches deep, so that when bolted to the gauge-piles, the space between them may be six inches wide. Also another row of double waling is to be bolted to each row of gauge-piles, at the distance of nine feet below the upper row before described, and to be of the same scantling, and fixed in the same manner as before described for the upper row of walings.

Dam Sheeting Piles.

The walings having been fixed, the dam sheeting-piles are to be pitched in the spaces between the main gauge-piles, and between the walings. The dam sheeting-piles to be not less than thirty feet long, and twelve inches by six inches scantling, to be shod with wrought-iron shoes of not less than nine pounds weight each, and to be hooped with best scrap iron, not less than two and a half inches broad, by five-eighths of an inch thick. All the piles to be driven down until their heads are level with the heads of the main gauge-piles before described.

Driving Engines.

The whole of the dam-piling to be executed with crab-engines, carrying a ram of not less than twelve hundred-weight for the main gauge-piles, and ten hundred-weight for the dam sheeting-piles, and proper stages to be erected for the perfect execution of the work.

Excavation.—Dam Sluice.

The dam-piling being completed, the soil is to be removed from between the outer and inner rows of piles, down to the depth of twenty-five feet below the before-mentioned quay-wall benchmark, and a sluice-trough inserted, so as to admit of the dam being easily filled with water when required, in case of floods or otherwise, to prevent its blowing up.

Dam Tie Bolts.

The soil having been removed from between the two rows of piles, the gauge-piles of the respective rows are to be connected by screw-bolts of round iron, one and a fourth inch diameter, passing through the centre of the walings. A wrought-iron washer of not less than four inches square, and three-eighths of an inch thick, is to be placed under the head and nut of these main-bolts, to prevent the walings giving way under the strain.

Puddle.

The excavated space between the piles is to be filled up with pounded clay, so as to render the dam perfectly water-tight.

Pumping Engines.

For pumping out the water from the dam, two steam-engines, of not less than fifteen-horse power each, are to be erected, one on each side of the river, and to be connected together by a timber rod, working upon rockers, and extending across the river in a line parallel to the centre line of the bridge. By this arrangement, the whole thirty-horse power may, if required, be applied to the pumping of each dam in succession; and it being expected that, in general, one engine will be sufficient for keeping down the water, the spare engine may thus be kept in efficient working condition, and the work advance without interruption, and independent of accidents happening to either of the engines. The pumps, rods, rockers, and all apparatus connected therewith, to be erected to the satisfaction of the resident engineer, previous to the operation of getting in the foundation-piling being commenced.

Measures to be adopted in case of the Sand blowing up into the Dams.

If, on pumping the water, or excavating the soil from the dam, it be found that the sand blows up from the bottom, in this case the foundation-piling, as hereinafter specified, is to be pitched, and driven down in order to consolidate the sand, so as to allow of its being excavated to the required depth; and if the foundation-piling do not sufficiently consolidate the sand, then, upon the first symptoms of blowing taking place, or of water springing up from the bottom, extra piles of common Scotch fir, of such length and scantling as the resident engineer shall determine, are to be driven between the main bearing-piles, or such other measures adopted as circumstances may require, and to the

entire satisfaction of the resident engineer, for excavating the soil to the required depth of twenty-five feet three inches below the quay-wall benchmark.

Excavation to be removed.—Dam to be braced.

No part of the soil excavated from the dam is to be thrown into the river, but removed either by punts or carts from the site of the bridge-works; and as the excavation proceeds, the dam is to be securely braced, to prevent its being burst in or twisted by the outer pressure.

The contractor will not be obligated to have more than two cofferdams in progress at a time, in order that the timbers, if drawn entire, may be again applied to the same purpose.

FOUNDATIONS.

Outside Foundation Piling.

The outside row of foundation-piling is to be of Memel, Dantzic or sound American red pine, in the execution of which gauge-piles of not less than twelve inches by twelve inches scantling, and fifteen feet long, are to be driven at the distance of six feet apart, measuring from centre to centre, and waling-pieces bolted thereto, for the purpose of keeping the intermediate sheeting-piles in a true line. The sheeting-piling is to be of twelve inches by six inches scantling, each pile twelve feet long, and opposite each joint an additional sheeting of twelve inches by three inches scantling is to be driven down to the depth of six feet; all which piling is to be firmly connected together by a waling of twelve inches by three inches scantling, as shown by the drawings.

Inside Foundation Piling.

The inside bearing-piles are to be of beech, or sound Scotch fir, newly-cut, each pile to be not less than eight inches diameter in the middle of its length, clear of the bark, and be not less than twelve feet long, and of strait growth.

Hooping and Shoeing.—Length and Scantling of Piles to be altered, if required.

The whole of the foundation-piling is to be pitched in the position shown by the drawings, to be shod with wrought-iron shoes of not less than nine pounds each, to be hooped with best scrap-iron, not less than three inches broad, by five-eighths of an inch thick, and be driven down until the head of each pile is twenty-three feet three inches below the aforesaid quay-wall benchmark, and all the heads to be cut off at the exact level of twenty-four feet three inches below the aforesaid benchmark, to receive the foundation-sleepers and platform; but if, on proving the ground, a greater or less length of piles be found more advisable by the resident engineer, an addition to, or deduction from, the amount of the contract is to be made, agreeably to a schedule of prices which the contractor is to annex to his tender, for the purpose of fixing the prices at which all extras or deficiencies of work performed are to be rated.

Foundation Handset Packing.

The piling having been completed, and the soil taken out to the depth of one foot below the heads of the piles, this space is to be made up with handset rubble, well packed, and laid flush in good water-lime mortar, as hereinafter specified.

Foundation Sleepers.

Upon each transverse row of piles there is to be laid a sleeper, extending across the pier or abutment, in one log of twelve inches by six inches scantling, to be secured to the head of each pile by a wrought-iron ragged-bolt, of not less than three-fourths of an inch iron, and fifteen inches long, and the spaces between the sleepers to be filled with handset rubble, laid in good water lime-mortar.

Platforms.

Upon the sleepers two floors of three-inch planking, of Dantzic, Memel or American red pine, crossing each other at right angles, are to be spiked down with spikes not less than six inches long, and weighing one-third of a pound each, driven in the positions shown by the drawings.

MASONRY.

Courses up to the Bed of the Impost.

The foundation-platforms having been completed, the masonry may be proceeded with; the general form and particular dimensions are distinctly shown in the before-mentioned drawings. The foundation-course of each of the piers and abutments to be each eighteen inches thick, the next succeeding three courses to be each sixteen inches thick, and the remaining courses, up to the bed of the impost (which is to be level with the quay-wall benchmark before referred to), are to be each of them not less than fourteen inches thick; but if it be found necessary to lay the foundation-course of masonry at a different level to that shown by the drawings, and herein specified (viz., twenty-three feet three inches below the quay-wall benchmark), the extra or deficiency of work is to be settled for agreeably to the schedule of prices before referred to.

Piers and Abutments.

The thickness of the piers in the dado to be eight feet, eight feet six inches, and nine feet; the thickness of the abutments to be eight feet at the springing of the arch, exclusive of the abutment counterforts, as shown by the drawings, and the eight offsets of four and a half inches each, on the foundation-courses of the abutments and piers.

Dressing of Ashlar.

The whole of the stones of which the piers and abutments are composed must be truly squared throughout; they are to have chisel-drafts round the faces, beds, backs and end-joints, and to be truly pick-dressed between the drafts. The outside face-work, from the foundation up to the offset below low-water line, to be broached in horizontal lines, not coarser than eighteen in a foot.

Granite Facing of Piers and Abutments.

From the offset below low-water line, up to the impost, the towers and the sides of the piers and abutments, extending to an average of two feet within the line of the face of the arch quoins, are to be faced with granite, of uniform quality and colour, from the quarries in the neighbourhood of Aberdeen, Castle Douglas or Kingstown, near Dublin, all (both as regards quality, colour and workmanship) agreeably to the respective specimens

in the possession of the resident engineer. Each side of the bridge is to be faced with granite from one of the above-named quarries; no mixture of stones to be allowed, but both sides of the bridge are not restricted to be faced from the same quarry.

Workmanship of Granite Facing.

The granite facing below the imposts to be laid in alternate courses of headers and stretchers; the headers to be not less than two feet in length of face, and not less than two feet on the bed; the stretchers to be not less than two feet six inches in length of face, and not less than one foot on the bed. Each stone to be truly squared, and fair-dressed on the beds and joints full throughout; the backs scapelled, and the fronts rough-picked, agreeably to the pattern in the possession of, and to be kept by, the resident engineer; the front arris' to be neatly axed or chisel-drafted, to make a close joint on the face.

Ashlar Hearting.

The hearting masonry of the piers and abutments to be squared ashlar, well-dressed, and laid in courses of uniform thickness throughout, agreeably to the thickness of the facing; no stone to contain less than four feet superficial on the bed, and each stone to break joint with the adjoining stones at least one foot.

Freestone Masonry of Piers and Abutments.

Such parts of the sides of the piers and abutments as are not composed of granite are to be laid in alternate courses of headers and stretchers of durable quality, as hereinafter specified; no stone of the header-courses to be less than two feet on the outside face, or reach less than three feet into the body of the work. No stone of the stretcher-courses to be less than three feet in length of face, and two feet in breadth on the bed. No stone for the interior work to contain less than four superficial feet on the bed, and to be of the same thickness as the outside stones. All the masonry to be square-dressed throughout, to be laid on its natural bed flush in good lime-mortar, of a quality which will harden under water, as hereinafter specified, used while fresh.

Imposts and Arch-springers.

The imposts and arch-springers are to be worked together out of the same stone, of the form and dimensions shown by the drawings; the impost projecting three inches before the face of the dado part of the piers, and the arch-springers truly radiated to the centre of the circle, of which each arch respectively is a segment. The continuation of the impost and springers round the towers to be of granite, fair-dressed on the beds and joints full throughout, the backs scapelled, and the fronts pick-dressed; the front arris' to be neatly axed or chisel-drafted, to make a close joint on the face.

Backing of Imposts and Springers.

The space between the backs of the imposts and springers to be filled with three courses of ashlar masonry, each one foot thick, of hard and well-squared stones, carefully bedded and closely jointed.

Centring.

The arches to be constructed on properly-framed centring, of such construction as the contractor may find most suitable for the timber then on hand, but to be of undoubted sufficiency, and supported upon slack blocks, admitting of the centres being lowered at least six inches; the setting of the arch-stones not to be commenced until two complete centres are erected.

Arch-stones, Dimensions and Workmanship.

The arch-stones to vary in depth from two feet in the abutment arches, to two feet six inches in the middle arch, as marked on the elevation; the thickness of the courses may be varied from fifteen to thirteen inches for the middle arch, and from twelve to ten inches for the abutment arches; the intermediate arches to be taken in proportion; the thickest courses to be nearest the springing, and diminish gradually to the key-stone, and each course to be of the same thickness quite across the soffit; no arch-stone to be more than three feet six inches, nor less than two feet six inches, in length, and each to break joint with the adjoining stones, at least one foot; the beds to be truly radiated, to be chisel-drafted round the edges, and neatly pick-dressed within the drafts; the soffit faces to be neatly broached in horizontal lines parallel to the bed, and chamfers three inches wide and one inch and a half deep for the centre arch; and two inches and a half wide and one inch and one-fourth deep for the arches next the abutments; are to be cut upon the soffit-joints, and up the face of the quoins; all the stones to be carefully bedded in good water lime-mortar, as hereinafter specified, and each stone brought firmly to its bed with a wooden maul.

Arch-Quoins, or Ring-Pens of Granite.

The quoins or ring pens of the arches to be of granite, consisting alternately of stones two feet six inches and one foot six inches in length of bed on the soffit, and of the respective depths and thicknesses before described for the freestone arch-stones; each stone to be truly radiated, to be fair pick-dressed upon the beds and joints full throughout; the face and soffit to be neatly axed, and the front arris' to be axed or chisel-drafted, to make a close joint on the face.

Spandrel Facing.—Granite.

The exterior spandrel walls are to be two feet six inches in thickness, to have semi-octagonal towers over the piers and abutments, and sunk panels, as shown on the elevation; the facing to consist of granite masonry; the stretchers to be twelve inches on the bed, and one-fourth of the surface of each course to be headers, passing at least one foot nine inches into the solid of the wall; no course to be less than fourteen inches in height, or more than sixteen inches; the thicker courses to be undermost, and each stone to be at least two feet six inches in length of face, and to break joint with the adjoining stones at least one foot.

Spandrel Panels.

The panels to be sunk four and a half inches within the face of the spandrel walls, all to be pick-dressed upon the beds and ends full throughout; the faces to be axed agreeably

to the specimen in the possession of the resident engineer, and the arris' round the face to be neatly axed or chisel-drafted, so as to make a close joint on the face.

Rubble Backing of Spandrels.

The backing to consist of hammer-dressed rubble masonry, laid in regular courses on their natural bed, not more than two stones in thickness for one of outside ashlar, all to be properly bonded with the facing stones and amongst themselves.

Interior Spandrels.

The interior spandrel wall which supports the curb and gutter stones to be two feet two inches thick, corbelled at the top, as shown by the drawing, to receive the flag-founds below the footpath pavement. The intermediate spandrel wall under the centre of the footpath to be one foot six inches thick, exclusive of the corbelling; the whole to be of good rubble masonry, hammer-dressed, and laid flush in good water lime-mortar, upon horizontal beds.

Spandrel Hearting.

Between the backs of the arch-stones the spandrels are to be built up solid to the height of the flood-line, being four feet six inches above the top of the arch-springers, with good hammer-dressed rubble masonry, laid in regular courses on horizontal beds, well flushed in water lime-mortar, as hereinafter specified, and packed hard against the backs of the arches.

Cross Walls.

Upon the before-mentioned masonry, over each pier and abutment, a cross wall, five feet thick, is to be carried up to the level of the under bed of the facia course; this is also to be good rubble masonry, as before described. Also the spandrel walls, under each footpath, are to be connected together with cross walls, one foot six inches thick, as shown by the drawings.

Abutments.

The abutments are to be constructed agreeably to the form and dimensions represented by the drawings. The interior masonry to be of square-dressed ashlar, as before described, up to the level of the top of the arch-springers; thence up to the level of the bed of the facia course the work to consist of good hammer-dressed masonry, laid in regular courses, not less than seven inches thick, and all flushed in water lime-mortar. The exterior to be faced with granite, as before described, for the piers.

Spandrel Packing.

The voids of the spandrels are to be filled up with broken stone-chips, firmly pounded up to the level of the bed of the facia course, upon which the concrete and carriage-way materials will be laid.

Granite Cornice.—Facia Course and Cordon.

A facia course and cordon, making together two feet three inches in height, are to be laid along each side of the bridge, and round the semi-octagonal pilasters of the piers and abutments, as shown by the drawings. The facia is to be twelve inches in thickness, and

one foot nine inches in breadth on the bed; it is to project four inches over the face of the spandrel walls.

The cordon course and its fillet are to be in one stone, one foot three inches in thickness, moulded as represented by the drawings.

The facia and cordon are to be of granite, of which no stone is to be less than three feet in length of face, to be fair-picked upon the beds and ends full throughout; the faces to be well axed, and the arris' round the face to be axed or chisel-drafted, to make a close joint.

Granite Parapet.—Construction and Workmanship.

Upon the cordon course the parapet is to be placed, of which the base course is to be fourteen inches in breadth on the bed, and nine inches in height; the dado twelve inches thick, and two feet six inches in height. The coping to be fourteen inches broad, and nine inches in height; but the coping, constituting the caping of the semi-octagonal pilasters or towers, is to be executed, as shown by the drawings, only one stone in thickness, up to the base of the octagonal pedestal for the lamp-post, and the caping of each semi-octagonal tower to consist of only two stones, close-jointed in the middle. The base course, dado and coping, to be each one course in height, and each stone to be not less than three feet long. The whole to be of granite, neatly picked upon the beds and ends; the whole of the exterior, and parts exposed to view, to be neatly double-axed, agreeably to the specimen in the possession of the resident engineer. The arris' to be chisel-drafted, or double axed, to make a very close joint, and the whole to be set in fine water lime-mortar, ground expressly for this part of the work. Each joint of the coping is to be secured by a cast-iron dowel, one and one-fourth inch square, and four inches long, let into the centre of each stone, and set with Roman cement.

Wing-walls.

Wing-wall Piling.

The wing-walls are to be founded upon a piled platform, of the form and dimensions shown by the drawings. The piles to be of larch, or sound Scotch fir, newly cut, of strait growth, varying gradually in length from ten feet, at the back of the abutments, to seven feet for those under the newels at the termination of the wing-walls; each pile to be not less than eight inches diameter in the middle of its length, exclusive of the bark, to be shod with a wrought-iron shoe, of not less than seven and a half pounds weight, and to be sufficiently hooped, to prevent its splitting upon being driven.

Wing-wall Walings.

The heads of the piles to be connected with pairs of walings of twelve inches by three inches scantling, bolted together with a screw-bolt of not less than three-fourths of an inch round iron through the head of each pile; the piles being driven, and the walings bent to a curve, agreeably to the curve of the face of the wing-walls.

The spaces between the pile-heads and between the walings to be made up hard with stone shivers, well pounded to the level of the top of the before-mentioned walings.

Planking.

A platform of Baltic timber or American red pine is to be laid three inches thick, spiked to the walings with six six-inch spikes to each plank, being one spike into each waling. Upon this planking the foundation course of masonry is to be laid.

Granite Facing of Wing-walls.

The outside facing of the wing-walls is to be of granite, consisting of headers and stretchers, the stretchers to be at least one foot on the bed, and two feet six inches in length of face, and one-fourth of the whole surface to be headers bonding at least one foot nine inches into the wall, and each stone not less than two feet in length of face. The beds and ends to be pick-dressed full throughout, the front arris' to be chisel-drafted or neatly axed, so as to make a close joint on the face, the face to be rough pick-dressed between the drafts, agreeably to a pattern, and each stone to break joint with the adjoining stones at least twelve inches. The courses to be laid horizontal, and to range with the courses of the abutment octagons.

Rubble Backing of Wing-walls.

The backing to be of good rubble masonry laid in regular courses, well bonded with the ashlar facing, all to be laid in horizontal courses of not more than two stones in thickness for one of outside granite facing. The walls to be solid up to the level of the top of the arch-springers.

Extent of Wings.

Each of the wing-walls is to be extended as shown by the drawings, the centre of the terminating newel being sixty feet behind the face of abutments, making the whole length of the bridge, measuring from centre to centre of the wing-wall newels, five hundred and sixty feet.

Wing-wall, Facia and Parapet.

A granite facia course one foot three inches deep, and one foot six inches on the bed, dressed as before described, for the facia course of the cornice, is to be laid along the whole extent of the wing-walls, and round the newels, projecting three inches from the face of the wings; upon this the parapet walls are to be placed, which are to be of the same dimensions, material and workmanship before described, and agreeably to the drawings thereof.

The voids of the wing-walls, and the whole space between the opposite wing-walls, are to be filled up with quarry shivers, or dry building rubbish, and be well pounded up to the required level, to receive the carriage-way materials, as hereinafter specified.

Gutter and Curb Stones.

Upon the interior spandrel-walls along both sides of the bridge, and extending along the wing-walls, there is to be laid a gutter-stone and a curb-stone, as shown by the drawings.

The gutter-stone is to be of Aberdeen granite, fourteen inches wide and nine inches deep, having a triangular water-channel cut into it four inches deep and eight inches wide.

The curb-stone is also to be of Aberdeen granite, fifteen inches deep and twelve inches thick, having the outer angle rounded off, and the interior angle checked down four inches, to receive and support the footpath pavement.

The gutter and curb-stones are to consist of stones not less than three feet long, to be axed upon the faces exposed to view, and having the joint arris' chisel-drafted; or neatly axed, to make a close joint; the whole to be set in good water lime-mortar, as hereinafter specified.

Construction and Workmanship of Footpath Pavement.

The footpath pavement extending along both sides of the bridge, and along the wing-walls, is to consist of an under-course of founds, and an upper course of dressed flag; the under-course, being the spandrel covers, is to be composed of sound hard founds, six inches thick, to be closely jointed, and laid flush in good water lime-mortar. The upper course is to consist of sound Caithness or best Arbroath hard flag pavement. The width of each footpath is to be nine feet, measuring from the dado of the parapet to the outside of the curb-stone, which being eight inches wide, exclusive of the check of four inches, leaves the width of flagging to be eight feet four inches, which is to be laid in regular courses of not more than three stones in any course, breaking bond not less than one foot; no stone to be less than three inches thick, or contain less than six feet superficial on the face, the whole to be laid close jointed, and well flushed in good water lime-mortar. The top surface of the footpath to be neatly broached, and have a uniform inclination from the parapet towards the gutter-stone, of three inches on the entire width of nine feet, and the top of the curb-stone to be six inches above the gutter-stone.

Carriage-way Concrete.

The carriage-way over the bridge, and to the extremity of the wing-walls, to be formed as follows:—The stone shivers and dry building rubbish, with which the spandrels and spaces between the wings are to be filled, having been well pounded, the whole is to be covered with a bed of lime and gravel concrete, well mixed, in the proportion of four measures of clean gravel to one measure of water lime-mortar, as hereinafter described, used while fresh; this bed of concrete is to be nine inches thick at the sides of the carriage-way, next the gutter-stones, and one foot thick in the centre of the road; the surface forming a uniform curve, agreeably to the curve of the surface of the road, as shown by the drawings.

Causeway.

Upon the bed of concrete there is to be laid a well-dressed whinstone causeway, in regular courses across the road, between the gutter-stones. Each stone of this causeway to be hammer-dressed to a rectangular oblong form, about twelve inches long, nine inches deep, and not more than five inches thick, or less than four inches, all to be laid dry upon the bed of concrete, grouted with Arden or Aberthaw lime, and beaten down with a heavy bishop, so as to form a uniform curve, of which the crown is three inches above the top of the gutter-stone.

Drain Pipes.

The water is to be carried off by cast-iron pipes, six inches diameter, passing through the key-course of each of the arches excepting the middle arch, and reaching three

inches below the soffit of the arch; also by a drain at each of the newels, as shown by the drawing, to connect with the common shore.

Granite Quarries.

The granite required for the different parts of the work before specified is to be either from the quarries in the neighbourhood of Aberdeen, of Castle Douglas, or of Kingston, near Dublin, and agreeably to the specimen of each, now in the possession of, and to be kept by, the resident engineer.

Freestone Quarries.

The stones composing the remaining ashlar and rubble to be of sound, hard and durable quality, to the satisfaction of the resident engineer, from Netsill Quarry, Possil Quarry, Dundas-street Quarry, Whole Burn Quarry, Moss Quarry, and Willox's Quarry, near Pollockshaws, or Giffnock Quarry, or such other quarries only as shall be specified in writing by the resident engineer, and approved of by the superintendent for the time being of the public works at Glasgow.

Lime.

For the whole of the masonry work and concrete before specified, none other than Aberthaw lime, blue lias lime, Arden lime, or Lord Elgin's lime from the Firth of Forth, being those most approved for waterworks, is to be used, unless specially authorized in writing by the resident engineer.

Mortar.

The mortar is to be composed of lime of the above description mixed with clean sharp sand, in such proportion as shall be found most suitable to the kind of lime adopted for making the strongest mortar.

Contractor to find all Materials, Labour, Implements, &c.

The contractor is to find all materials and labour, all engines, pumps, machines, tools, cofferdams, scaffolding and centring, necessary to complete the bridge and roadway to the extremity of the wing-walls, agreeably to the plans and this specification, and to the entire satisfaction of the committee of management, and of the engineer appointed by them to superintend the execution of the works.

Payments every Two Months by Measure and Value—less 10 per cent.

During the progress of the work, measurements are to be made every two months by the resident engineer of the quantity of work performed, and the value thereof is to be estimated by a scale of prices to be fixed by the principal engineer, such scale of prices being so rated that the whole of the works contracted for, being measured and valued agreeably thereto, the total amount shall be the exact sum for which the whole of the works are contracted to be executed, and one-tenth part being deducted from the value of the work performed every two months, the remainder is to be paid to the contractor upon his presenting the certificate of the resident engineer to the treasurer of the bridge

trustees, and the tenth part so deducted from each payment is to be retained by the treasurer as additional security for the due performance of the work in all respects agreeably to this specification, over and above the amount of security hereinafter mentioned; and within one month after the bridge shall have been completed and taken off the contractor's hands by the committee of management, the tenth part, deducted as before mentioned from each payment, is to be paid to the contractor.

Accommodation Ground.

The contractor will be allowed the use of part of the south quay of the harbour, also of the plots of ground situated on both sides of the river above bridge, extending in length from the east end of the Broomielaw harbour, up to the New Wooden Bridge, and in breadth from the north bank of the river, up to the railing bounding Great Clyde-street, and from the south bank of the river, up to the railing bounding Carlton Place, but subject to the obligations narrated in pages 524 and 525 hereof.

Time allowed.

The whole of the works, whether generally or particularly described in the foregoing specification and drawings referred to, are to be executed to the entire satisfaction of the principal and resident engineer appointed by the trustees, and to be carried on with all creditable and proper expedition, so as to be completed by the 31st December 1836.

Works to proceed according to the Specification, or otherwise, as the Trustees direct.

The trustees reserve to themselves full power to make such alterations regarding the depths, lengths and widths of the foundations, width of soffit of arches, width of footpath and carriage-way, quality and scantling of materials to be used, and general construction, as they may determine upon from time to time during the progress of the work; but no alteration or deviation whatever is to be made from the plans and this specification, without express directions in writing from the resident engineer, acting under the authority of the committee of management; and should any part of the works be executed otherwise than as herein specified, the resident engineer shall have full power to order the same to be taken down or otherwise rectified, at the expense of the contractor. And all such deviations as shall be made by the written authority of the resident engineer, shall, upon being measured, be settled for, agreeably to a schedule of prices of the form hereinafter specified.

Power of the Trustees to effect the Completion of the Work within the time specified.

And should it at any time appear to the satisfaction of the committee of management that the contractor is not carrying on the work in all respects agreeably to this specification, or delaying the execution thereof, from death, bankruptcy, or any other cause, it shall be in the power of the trustees to employ additional workmen, at the expense of the contractor, or to take the work out of his hands, and either enter into a contract with others for completing the same, or employ workmen under their own direction, or that of their resident engineer, at the expense of the contractor or of his sureties, deducting all expenses so incurred from his contract price.

Security.

The contractor or contractors are required to find security to the amount of £.7,000 for the due performance of the work and its perfect completion, agreeably to the drawings and this specification.

Trustees not obliged to accept the lowest Tender.

It is to be expressly understood, that the trustees do not obligate themselves, and are not required, to accept the lowest tender, and reserve to themselves full power to accept of any tender that may be given in, or to make any arrangements which they may find practicable, and, in their own opinion, in any respect advisable to be made.

Arbiters appointed.

All matters of disagreement between the contracting parties are to be settled by reference to Thomas Telford, Esq., principal engineer to the bridge trustees; or, failing him, from indisposition or otherwise, by James Cleland, Esq., superintendent of public works for the city of Glasgow, or, failing him, from indisposition or otherwise, by a qualified person, to be named by the said trustees, and the decision of such arbiter shall be final and binding upon all parties, and not subject to revision from any court of law or otherwise.

Thomas Telford.

London, 6th November 1832.

Tender with Estimate, how to be drawn out.

Each contractor or contracting party is to state in his tender letter, the gross sum for which he will engage to erect the bridge complete, and in all respects as above specified, distinguishing the three different kinds of granite, as follows:

	£. s. d.
If Aberdeen granite be used - - - - - -	
If Galloway granite be used - - - - - -	
If Irish granite be used - - - - - - -	

Also, with the tender, there is required to be given in a schedule of prices of the form hereunto annexed, for the purpose of fixing the prices of such extra work, or deductions from the plan, as the trustees may from time to time direct. Such schedule of prices, when applied to the measurement of the different kinds of work contained in the bridge, is to give the gross amount demanded for the due completion of the work, agreeably to the drawings and specification.

N. B.—The iron gratings, pipes, lamps, lamp-posts, and octagonal bases are not to be included in the bridge contract.

SCHEDULE of PRICES for regulating the Payments for Extra Work, or Deductions which may be made during the progress of the Work, by order of the Bridge Trustees.

		Measurement.			How Rated.	Rate.	
		Yds.	Ft.	In.			£. s. d.
1	Gauge-piles, 12 inches by 12 inches, scantling for the cofferdams (red pine) -				At p' cub. ft.		
2	Ditto - driving at per cubic foot driven into the ground, including all labour -				"		
3	Sheeting-piles, 12 inches by 6 inches, scantling (red pine) - - - - - -				"		
4	Ditto - driving at per cubic foot driven into the ground, including all labour -				"		
5	Walings and bracings, 12 inches by 9 inches, scantling, including all labour of fitting, fixing, &c. - - - - -				"		
6	Pile-shoes - - - - - - - -				At p' lb.		
7	Dam tie-bolts, nuts and washers, and pile-hoops (allowing 1 hoop to 10 piles) -				"		
8	Small screw-bolts, nuts, washers and spikes				"		
9	Excavation, measuring only the space actually made void, and not to include the soil, which from any neglect may be allowed to blow into the dam - -				At p' cub. yd.		
10	Clay-puddle, including all labour - -				"		
	N. B.—The whole of the materials, after being applied to their respective purposes, are to be the property of the Contractors.						
11	Gauge-piles, 12 inches by 12 inches, scantling, in outside row of foundation-piling (red pine) - - - - - - - -				At p' cub. ft.		
12	Ditto - driving, at per cubic foot, driven, including all labour - - - - -				"		
13	Sheeting-piles, 12 inches by 6 inches, scantling, &c., 12 inches by 3 inches, scantling (red Quebec pine) - - - -				"		
14	Ditto - driving ditto, at per cubic foot driven - - - - - - - -				"		
15	Interior bearing-piles, round timber, (Scotch fir) - - - - - -				"		
16	Ditto - driving, including all labour of dressing, shoeing, &c. - - - - -				"		
17	Walings 12 inches by 8 inches, scantling, including all labour of fitting and fixing (red pine) - - - - - - - -				"		
18	Sleepers, 12 inches by 6 inches, scantling, including all labour of fitting and fixing (red pine) - - - - - - - -				"		
19	Platform planking, 3 inches thick (red pine)				"		
20	Pile-shoes - - - - - - - -				At p' lb.		
21	Screw-bolts, nuts, washers, spikes and hoops (allowing 1 hoop to 10 piles) -				"		
22	Rubble, packing below platforms - -				At p' cub. yd.		
23	Freestone, masonry below bed of impost, including lime and all labour - -				At p' cub. ft.		

		Measurement.			How Rated.	Rate.	
		Yds.	Ft.	In.			£. s. d.
24	Granite facing below bed of impost, including lime and labour, &c. (Aberdeen granite)				At p' cub. ft.		
25	Ditto - - ditto - (Galloway granite)				"		
26	Ditto - - ditto - (Irish granite) -				"		
27	Impost and arch-springers (freestone) complete, including lime and all labour -				"		
28	Ditto - (Aberdeen granite) - ditto -				"		
29	Ditto - (Galloway granite) - ditto -				"		
30	Ditto - (Irish granite) - - - ditto -				"		
31	Freestone, ashlar backing of imposts and springers - - ditto -				"		
32	Arch-stones (freestone) - - - ditto -				"		
33	Ditto ring-pens (Aberdeen granite) ditto -				"		
34	Ditto - ditto (Galloway granite) ditto -				"		
35	Ditto - ditto (Irish granite) - ditto -				"		
36	Facing of spandrils and towers (Aberdeen granite), including lime, labour, &c. -				"		
37	Ditto - - (Galloway granite) - ditto -				"		
38	Ditto - - (Irish granite) - - ditto -				"		
39	Facing of wing-walls and newels (Aberdeen granite) - ditto - - -				"		
40	Ditto - - (Galloway granite) - ditto -				"		
41	Ditto - - (Irish granite) - - ditto -				"		
42	Rubble masonry in spandrils, wings, spandril-hearting, cross-walls - - ditto -				"		
43	Facia course and cordon of cornice (Aberdeen granite), including lime, labour, &c.				"		
44	Ditto - - (Galloway granite) - ditto -				"		
45	Ditto - - (Irish granite) - - ditto -				"		
46	Base, dado and coping of parapet (Aberdeen granite) - ditto - - -				"		
47	Ditto - - (Galloway granite) - ditto -				"		
48	Ditto - - (Irish granite) - - - -				"		
49	Gutter-stone and curb-stone (Whinstone) - - ditto -				"		
50	Ditto - - (Aberdeen granite) ditto -				"		
51	Flag founds, 6 inches thick (freestone) - ditto -				At p' yd. sup.		
52	Flag pavement for footpaths (Caithness) set complete - - ditto -				"		
53	Ditto - - (Arbroath best) - - ditto -				"		
54	Filling up spandrils, and between the wing-walls with quarry shivers and rubbish -				At p' yd. cub.		
55	Gravel concrete as specified (Arden lime)				"		
56	Ditto - - (Corry lime, Isle of Arran) -				"		
57	Ditto - (Lord Elgin's lime, Firth of Forth)				"		
58	Whinstone causewaying for carriageway, as specified - - - - - -				At p' yd. sup.		
59	Pumping engines, and all expenses of pumping for the bridge, as specified -				A gross sum.		
60	Centring, service timber, gangways, &c. -						
61	Cranes, and all other machinery, tools, &c.						
62	Incidents, &c. - - - - - -						
	Total amount of Tender - -						

In case of its being found expedient to alter the depths of the foundations of any one pier or abutment, contractors are also required to state, in the following form, what extra charge or deductions will be made for each foot of perpendicular depth, on account of pumping, incidental expenses, and all matters which, from their nature, are not capable of being actually measured and rated by schedule prices.

	£. s. d.
Extra pumping and risk, &c., for 1 foot of extra depth, on any one pier or abutment - - - -	
Ditto - - ditto - - for 2 feet of extra depth - - -	
Ditto - - ditto - - for 3 feet of extra depth - - -	
Deduct pumping and risk for 1 foot of depth on any one pier or abutment less than specified - -	
Ditto - - ditto - for 2 feet less than specified - - -	
Ditto - - ditto - for 3 feet less than specified - - -	

Obligations on the Contractor relative to the use of the Accommodation Ground.

In order as far as possible to prevent injury to the accommodation ground, and detriment in any respect to the adjacent properties, the contractor must become subject to the following obligations, so long as the ground remains occupied by him.

1st. The space set apart for the use of the contractor shall be enclosed with a strong wooden railing, closed in towards the street with sarking boards, so as to cause as little encroachment as may be upon the street.

2d. Gateways are to be placed in such positions as the resident engineer may fix upon, so that the whole or any part of the materials deposited upon the ground, and subsequently transferred to the bridge, may not be conveyed upon the public street, but wholly within the space allotted to the contractor.

3d. To prevent damage from any part of the ground being overloaded with stones or other heavy materials piled upon it, or otherwise, the contractor shall engage to preserve and maintain effectually, during the occupation of the ground by him, all the common sewers, tunnels and valves in that part of the ground occupied by him, and rebuild, replace and repair any of the said common sewers, tunnels or valves that may be destroyed, damaged or injured by his operations, and leave the same in a perfect and complete state of repair; and that at the sight of Mr. James Morton, engineer, or of any other competent person to be named by the bridge trustees, such person having at all times free access to inspect the said common sewers, tunnels and valves.

4th. The contractor shall be bound to use his utmost care, and endeavour to preserve all the trees upon the ground, and for that purpose, especially, to surround each of the trees with a strong railing of wood; and such of the said trees as may be destroyed shall be replaced by such trees as shall be fixed upon by two neutral men, to be mutually named by the bridge trustees and the proprietors of the adjacent properties.

5th. The contractor shall become responsible to the bridge trustees for all kinds of nuisances committed upon the ground set apart for his use; and shall keep in constant

pay two able-bodied watchmen, for the express purpose of preventing such nuisances, as well as for the purpose of guarding the materials deposited on the ground.

Measurement.

The trustees have, for their own private satisfaction, caused a measurement of the works contained in the bridge to be made by an ordained measurer, which the respective contractors may inspect; but this liberty is granted upon the express condition, that the trustees do not guarantee the accuracy of the said measurement, and that the ultimate settlement for the works may be in no respect whatever affected thereby.

Appendix (O. 1.)

HOLYHEAD ROAD;—[*Braunston hill* and *Stow Hill*, near *Coventry*.]

Specifications.

Fo.. making the improved line of road over Braunston Hill, in the parish of Braunston, and county of Northampton, and likewise for constructing the necessary drains, fences and field-gates, all according to the accompanying plans and sections, upon which the dimensions are marked in figures.

The said improvement is to commence on the present mail road, between Braunston toll-bar and Berry bridge over the Oxford canal, at the red line across the road opposite the letter A. on the map and section, to continue upon said road across the canal a second time at Mr. Pickford's office, and through the village called Braunston wharf, to the point where the road bends a little to the south; it there enters the fields on the northern side of the present road, passes through the same by easy inclinations, and in a gently curving direction, to near the bridle road to Little Braunston, where it bends a little more to the south, and runs in nearly a strait line to the present road, which it joins finally at the red line across the road opposite the letter B. on the map and section, being a distance of about two thousand one hundred and fifty-six yards, or one mile and three hundred and ninety-six yards.

Road-making.

The surface of the road longitudinally or lengthways to be according to the sections, wherever these apply, and where they do not apply, the same to be marked off by the chief engineer for the Parliamentary Commissioners, or his assistant, but so as that none of the cuttings or embankings (except those in the said sections) shall exceed the depth of three feet.

The road is to be thirty-five feet wide between the banks of the fences, of which five feet on the southern side is to be occupied by a footpath, and the remaining thirty feet by a driving-way; where the ground is nearly level across, and neither cutting nor embanking are required, the bed for the metal is to be formed quite level, of the breadth of eighteen Footpath.

feet in the middle of said thirty feet. In doing this the natural surface to be disturbed as little as possible, so that the foundation for the metal may be vegetable mould. In all cuttings the side slopes to be two horizontal to one perpendicular: should hard stone be found in any of the cuttings, the same to be taken out for the use of the road to the depth of at least six inches below the surface of the slope, and its place supplied with good vegetable mould. In all embankments the side slopes to be the same as those of the cuttings, viz. two horizontal to one perpendicular, and the surface of them to be neatly dressed and covered with vegetable earth. A bed for the metal to be formed, as above described, in both cuttings and embankings. Upon said metal bed a bottom course or layer of stone is to be set seven inches deep in the middle, and five inches deep at the sides. The stones to be the full depth of the bed, to be of the hardest and most durable kinds got out of stone pits in Coventry Hill, or about Drayton, or in other pits where they can be had of similar quality. They are to be neatly set by hand in form of a close firm pavement; the lengthways of the stone to be across the road, the broadest edge to be downwards, and the upper edge in no case to exceed the breadth of four inches, all the inequalities of the upper part of the pavement to be broken off by the hammer, and all the interstices to be filled with stone chips firmly packed by hand, so as to form a regular convexity of two inches in the breadth of eighteen feet. The upper course or bed of metal to be of the best quality of stone to be got from the quarries or pits in the neighbourhood of Nuneaton, or at least of equally good quality. These stones to be broken into pieces, as nearly cubical as possible, so that the extreme points of every stone may pass through a ring of two and a half inches diameter, and that none shall exceed the weight of six ounces avoirdupois. The depth of said broken metal when consolidated to be six inches, and the breadth eighteen feet; over this is to be laid one and a half inch in thickness of good binding gravel. The sides of the metal to be shouldered, to within four inches of the finished surface, with good mould, and the said four inches in depth, for the remaining six feet on each side of the metal, including the side drains, to be made with the gravel now used for the present road properly cleansed and broken, care being taken to lay the hardest and best next the middle. The side drains to be sunk six inches below the metal bed, for the breadth of fourteen inches at bottom, and to be filled to within four inches of the finished surface with stone of the same quality as the bottoming, upon which the four inches of gravel is laid, and they are to be finished at the level of nine inches below the middle of the driving-way. Drains twelve inches wide and six inches deep below the metal to be made from the middle of the road, with proper declivities into these side drains; their situation and distances to be determined by the inspector; their number to be one for every sixty yards in the length of the road: they are to be filled with stones, as shown in the plan and cross sections. Sufficient time to be allowed for the complete consolidation of all embankments (to be determined by the inspector) before the metal is laid upon them. The footpath is to be coated with three inches of bottoming stone broken very small at top, and covered with one inch of small binding gravel, and when finished, to be on a level with the middle of the driving-way. The outer edge of the footpath to be protected by a firm sod, set with the green side out, and well compacted by the spade; the earth to be cut away from the top of the sod in a slanting manner from the outside,

Slopes.

Slopes covered across valley.

Pavement.

Metal.

Shouldering.

Side Drains.

Mitre Drains.

1 for 60 yards.

Coating of Footpath.

so as to admit the small stones and gravel to the outer edge, nearly as shown in the section.

Drainage.

Eight cross-drains of brick-work laid in lime-mortar, each fourteen inches wide within, to be constructed in every mile in length of the road; they are to be laid on a solid foundation, with an inclination at bottom of fully one inch in every ten feet in length, and at the depth of thirty inches below the surface of the middle of the metal bed. The side walls are to be about a foot in height, and the length of a brick in thickness. The bottom to be an inverted arch with bricks set on edge, and the curve in the middle to be two and a half inches: the cover to be an arch with bricks on edge, and the rise three and a half inches, making the height within at the centre fifteen inches. These cross-drains are to be continued under the fences into the ditches on each side, and when under embankments, they are to be carried to the extremities of the bottoms of the side slopes; they are to be firmly backed with earth well rammed, and covered with good turf, having the swarded side downwards; above this to the metal bed, good earth is to be laid and well rammed: should any drains of a different size be wanted, their situation, construction, number, size and value to be determined by the inspector. The water from the surface of the road to be introduced into the cross-drains by side openings or inlets of brick in bed laid in lime-mortar, ten inches by fourteen inches in the clear. The side and back walls of said side openings are to be raised four inches above the side-drains, and the front wall to be kept a little lower than said side-drains: they are to be covered with good sound stone, at least twenty-four inches long, fourteen inches broad, and two and a half inches thick. The whole of these inlets to be on the outsides of the driving-way, all as shown in the sections. The ends of the drains to be secured by stone masonry and paving, as shown in the section; the water to be introduced into the upper end of the cross-drain by a row of paving stones, raised above the bottom of it, and the outer row at the other end to be of large stones sunk so deep as to secure the whole from being removed by the current of water. Where a drain is connected with a water-course, the two ends are to be secured by wing-walls, at least five feet in length, and fifteen inches in thickness, carried to the springing of the covering arches, and covered by two rows of swarded turf, the lower one with the swarded side down, and the other with the swarded side up. When water is to be conducted from a ditch, similar wing-walls are also to be constructed. Wherever springs are found in the line of the road, or break out in any of the cuttings, the same to be carried into the ditches or natural water courses by proper under-draining, or otherwise, as the inspector may direct. Open cuts to be made wherever they may be necessary for conveying the water from the ditches into the natural watercourses.

Cross-drains, 8 in a mile.

Extra.

Ends of drains paved.

Wing-walls.

Fences.

The fencing to be constructed as shown in the section; a ditch to be cut, and a bank to be raised, together occupying seven feet and a half. The ditch to be on the field side of the bank, to be cut out of the natural ground, four feet wide at top, ten inches wide at bottom, and two feet and a quarter deep, on the southern or footpath side. The bank, three feet and a half wide, is to be raised by a sod, with the green or swarded side out, to

the height of ten inches above the footpath, and on the other side of the road, fourteen inches above the side-drain. Two rows of quicksets to be planted on the ditch side of the bank, as shown in the sections, and these to be protected by two rows of posts and rails on each side of the road. The row of the said fence next the field to have three rails in the height, and that next the road to have two. Where there is cutting, the two rows of quicksets, on each side of the road, to be at the average distance of three feet from the sides of the driving-way and footpath, and are to be planted in the middle of a bed of good earth; the breadth of the said bed to be two feet, and depth one foot; one row of the protecting fence to be placed on the top of the cut, and the other row between the quicksets and the road on each side. On all embankments, the two rows of quicksets on each side of the road to be also planted on a bed of good earth of the above dimensions, at the average distance of three feet from the upper edge of the slopes. A row of protecting posts and railings to be placed on the upper edge of each slope, and another row to be placed about four feet from the bottom of each slope. The number of thorns or quicksets to be not less than twelve in each yard in length. The posts, rails and quicksets to be similar to those used in that district of country.

Quicks, bed for.

Field-gates.

Ten field-gates, with iron hinges and fastenings, and ground-posts, all similar to the best kinds used in the adjacent country, to be furnished and erected. At each gate, drains, with good draining-tiles, not less than ten inches wide, to be laid in the side-drains of the road; and similar drains to the cross ones to be laid in the field or outside ditches. The length of these drains to be twelve feet, and proper roads to be made over them into the fields. The broken metal over the whole of the roads to be four inches in depth.

Drains.

Roads.

General Observations.

All the lines to be marked out by the person employed by the chief engineer for the Parliamentary Commissioners; and the general formation of the road is to be to his satisfaction. He is also to be satisfied with the solidity of all embankments, before the foundation or bottom course of pavement is laid upon them. The stone used for said bottom course, and the setting and packing of the same, are, in all cases, to be approved of by him before any broken metal is laid on. He is also to be satisfied that the top-metal is of proper quality and dimensions before the binding is laid on; and that the cross-drains are properly constructed, and firmly backed, before turf and earth are laid upon them.

July 3, 1821. *Tho[s] Telford.*

Appendix (O. 2.)

HOLYHEAD ROAD.—*St. Alban's* and *South Mims* Trust.

St. Alban's Improvement.

Specification.

For making the improved line of road from the Pond Yards through the town of St. Alban's.

This improvement is to commence at the letter A. upon the map and section; from thence it bends a little to the north, passes over the meadow-ground, crosses the river Ver, a little above Bow Bridge, proceeds along and adjacent to the back lane, leaving two cottages in the valley on the left hand, Prae Mill dwelling-house on the right hand, and two more cottages on the left hand, to the letter B. on the map. Here it enters Greatfield; crosses it; Riverfield; the hollow ground to the north of Kingsbury; the occupation-road in said hollow ground, and Kingsbury-lane. It then rises to the fields on the northern side of St. Alban's, passes over five fields there, and the hollow ground called New England's; afterwards over a small field, the site of a barn, stable, &c.; and after crossing Dagnal-lane, and the corner of Mr. Martineau's garden, it cuts a part of the poor-houses. From thence it crosses Spicer's-street, the sites of some cottages and gardens belonging to Mrs. Godbolt, Mrs. Moreton, Mrs. Grindon, Mr. Bunn and Mr. Kinder; the rope-walk possessed by Mr. Strobb; a footpath; the gardens belonging to Messrs. Bayly Smith and Thomas Jones; part of a malt-house belonging to the said Mr. Bayly Smith; the garden belonging to Mr. Haycock, and the free grammar-school; part of the out-buildings and court-yard of the George Inn; the pig-yard and some out-buildings of the Fleur-de-Lis Inn; a yard and some out-buildings belonging to Mr. Rinder; the out-buildings and a small part of the house belonging to Mr. Brooks; part of the sites of the out-buildings and court-yard of the Red Lion Inn, and some market-stalls. Here it joins the High-street of St. Alban's, and occupies the same to the Peahen Inn, where it finally terminates, at the letter C. upon the map and section.

The sites of the several houses and gardens are to be delivered over to the contractor free of buildings, or their materials.

The finished longitudinal surface upon which the road-materials are to be laid is to correspond with the red line on the section. The depths of cuttings and heights of embankings from the present surface of the ground (which surface is marked by a black line) are marked in red figures; but the contractor is to satisfy himself as to the depth of the cuttings and heights of the embankings that may be necessary in consequence of the form of the surface of the land.

The breadth between the banks of the fences is to be thirty-six feet; thirty feet for a carriage-way, and six feet on the western side thereof for a footpath, excepting in the town of St. Alban's, where there is to be a footpath of six feet on each side of the carriage-way, making the total breadth there forty-two feet.

The slope of the western side of the cuttings, excepting in the town of St. Alban's, is to be three horizontal to one perpendicular. The distances between the bottoms of the slopes of the cuttings and tops of the slopes of embankments are to be as marked on the section.

The cross surface for the road-materials of the carriage-way is to be formed level; the vegetable mould is to be retained wherever it can be done; all stones above six ounces in weight are to be picked out and carried off said surface, and the same is to be made uniform and equal from side to side, as a foundation for said materials.

The cross surface for the hard materials of the footpath is also to be formed level, and is to be ten inches above that of the carriage-way: drains fourteen inches wide and six inches deep below the said level surface, or bottom of the hard materials of the carriage-way, are to be cut on each side of it, at the distance of twenty-seven feet eight inches apart, and mitre or angular drains, to the number of twenty for each mile in length of the road, twelve inches wide and of the said depth of six inches, are to be cut across the road between the side-drains; they are to form such angles in the middle of the road as may be necessary for carrying the water into the side-drains; both of the mitre and side-drains are to be filled with rough flints connecting with the top course of road-materials, all as shown in the map of the road; and they are to be made every where but on the embankments.

Over the whole thirty feet of the carriage-way a coating of gravel is to be laid; it is to be seven inches deep at the middle and two inches at the sides, curving elliptically, according to the section. It is to be well screened once, and all stones exceeding two inches in length are to be taken out; after this body of gravel is laid on, it is to be well compressed, by carting upon it; the ruts and inequalities are to be kept constantly full by additional gravel, till a proper consistency, fit to receive the top dressing of hard clean-broken materials, is obtained. The breadth of the whole road of thirty feet is again to be coated with the hardest road-flints, to the depth of eight inches at the middle and four inches at the sides, also according to the section. They are to be broken into pieces as nearly cubical as possible, not exceeding two inches and a half in their largest diagonal dimensions. The footpaths of six feet in breadth are to be coated with five inches of clean flints or gravel, none exceeding two inches in their largest dimensions. A covering of one inch and a half in thickness of good binding gravel is to be laid over the whole carriage-way and footpath; that for the footpath to be quite free from clayey substances. An edging of turf, with the green side out, not less than eight inches in depth and five inches in thickness, is to be set in a neat compact manner on the outside of the footpath, and the top of it is to be covered with binding gravel. On the other side of the road, through all cuttings, a turf is to be set against the bottoms of the slopes in the same manner, and ten inches high by five inches in thickness. In the said cuttings, a similar edging of turf, six inches in depth and four inches in thickness, is to be set against the side of the benching for the quicksets, and a trench, eighteen inches wide at the top, six inches wide at the bottom, and fifteen inches deep, to be made between it and the quicksets, as shown in the section. The bottom of the trench to be very strait, and covered with two inches in thickness of small stones or large gravel.

From the cottages at the angle of Dagnal-lane to Spicer's-street, there is to be only one footpath, the same as on the other part of the road to the northward; but in place of a turf as above specified, the side is to be protected by granite curbing-stones, at least ten inches in depth and five inches in thickness. They are to be set two inches below the side-drains and eight inches above it; a pavement of flints is to be raised along the face of the curbing-stone, two inches and a half in height, leaving five inches and a half above, and it is to extend fifteen inches from said face, in a sloping direction outward, till it meets the surface of the finished road.

From the southern side of Spicer's-street to the same side of the Red Lion Inn, there is to be a footpath on each side of the carriage-way, the sides of which are to be protected with curb-stones and with pavement in the manner last described. The curbing stones are to be neatly dressed and jointed, and closely laid to each other.

Under each of the footpaths from the rope-walk where the cutting will commence to the said southern side of the Red Lion, and at the depth of three feet from the finished surface, drains of brick masonry, laid in good lime and sand mortar, are to be built, as shown in the section.

The side-walls are to be twelve inches in height of nine-inch work, and twelve inches in width in the clear.

The bottom of the drain is to be four and a half inch brick-work, paving a curvature of three inches, and the arch at top, of the same thickness, is to rise four inches, making the height within nineteen inches. The sides and over the top of the drain are to be well rammed with earth to the height of three inches above said drains, which leaves five inches for the coating of hard materials above described as a coating for the footpaths; the said drains shall be placed as the inspector may direct, and also the mitre drains in the cuttings. On the outsides of the said footpaths, leaving forty-two feet between, brick walls, laid in good lime and sand mortar, are to be built; they are to be laid on a good foundation at the depth of one foot below the top of the footpath, and to rise to the surface of the ground on each side; from the foundation to within three feet of the said surface, they are to be eighteen inches in thickness, and the said three feet at top is to be fourteen-inch work, including a coping of bricks fourteen inches long and six inches deep, with circular tops. The above description of walls applies to all the cuttings between the rope-walk and Red Lion Inn. From Mr. Searanche's cottages at the angle of Dagnal, to where the footpath will unite with Mr. Martineau's garden-wall, a similar brick and mortar wall is to be built along the side of the embankment. It is to be founded one foot below the surface of the ground, and raised to three and a half feet above the top of the footpath. From the same point of Dagnal-lane, on the eastern side of the road, to the junction of the road with the lane, a wall is also to be built, as specified above; and similar walls on the outsides of the footpaths, and on each side of the road, are to be erected from Spicer's-street to said rope-walk, where a thoroughfare passage must be left. All these walls are to be eighteen inches in thickness to the surface of the sides of the road and footpath, and the parapet of three and a half feet is to be fourteen-inches brick-work, including a coping of circular bricks as above described.

In crossing the Fleur de Lis and George Inn yards, where openings must be left and entrances made, the brick walls are to be returned, curving to the distance of eight feet on each side, within these entrances; or the same quantity of brick-work, in any other different shape, is to be used as the inspector may direct. The brick wall of the garden occupied by Mr. Martineau, which must be taken down for the site of the new road, is to be rebuilt of the same height, thickness and outside construction, with the old bricks well cleaned as far as they go, along the western side of said new road, and such a supply of bricks, equally good in quality, to be furnished as may be necessary to complete the same; to be laid in lime and sand mortar, two parts of sand to one of lime, well prepared and beat up, and used while fresh. The materials and workmanship to be in every respect equal to those of the present wall. An embankment is to be made along that part of the Dagnal-lane along the northern side of Mr. Martineau's garden. The inclination from the side of the new road is to be one in twenty, and it is to be coated with six inches in depth of the old materials, neatly applied.

On Spicer's-street an embankment is to be made from the side of the new road to meet the street by an inclination of one in twenty-two, curving neatly to meet the present surface, and a similar embankment to be carried up Dagnal-lane for thirty-six yards, curving as above to the present surface. Both these embankments are to be covered with eight inches in depth of old materials, or otherwise, well cleansed and broken to the aforesaid size of two and a half inches, neatly laid on. Brick walls are to be built along the sides of these approaches to the surface of the road, at such distances from the doors of the houses as may be judged proper for entrances; and the top is to be guarded with sawn post and railing of oak timber; the posts to be five by three inches and six feet long, the rails, two in the height, are likewise to be of oak, three and a half by one and a half inch, and seven feet long; the walls and railing may be about forty yards in length and about four feet in height of wall.

The connections between the rope-walk and the footpath to be made as good as they now are.

The George Inn and Fleur de Lis approaches are to be cut down to an inclination of one in twenty-two, and they are to be covered neatly with seven inches of old materials, or otherwise, prepared and broken as above described. The George Inn entry is to be ten feet wide, and the Fleur de Lis eight feet.

The connection between the new road, George-street, is to be made complete, by cutting down the latter and coating it with nine inches of the old materials, or otherwise, properly cleansed and broken, and joining said new road by an easy curving line. From the new road the breadth of Market-street will be, on an average, twenty-two feet. It is to be cut down from the side of the road, in an inclined plane, to the top of the Corn-market, and it is to be coated with nine inches in depth of the old materials, or otherwise, cleansed, broken and neatly laid on, with a surface shape, as may be fixed on by the inspector.

The space before the Clock-house and Fleur de Lis is also to be made strait and smooth, and the top of the well is to be lowered to the height of one foot above the new surface of Market-street opposite to it.

From the Red Lion Inn to the northern side of St. Peter's-street, and Holywell-hill, the driving or carriage-way is to be made thirty feet in breadth, and the footpaths are to remain as they now are. On the outsides of the driving-way, brick walls are to be built to the surface of said footpaths.

These walls, when above eighteen inches in height, are to be fourteen-inch work, and the eighteen inches is to be nine-inch work; they are to be founded six inches below the side channel of the road, and are to be coped with stones ten inches broad and four inches thick, neatly dressed and closely jointed, and the whole to be laid in good lime and sand mortar. Brick walls of the same description are to be built for protecting the footpaths, and giving room for carriages along Market-street. The total extent being about two hundred yards of walling two and a half feet high, including the coping.

Drainage.

There is to be at the rate of six cross-drains of brick masonry in every mile in length of the road; they are to be laid in a solid foundation, with an inclination of one inch for every ten feet in length of the drain, and at the depth of thirty inches at least from the surface upon which the road materials are laid; the side-walls are to be one foot in height of nine-inches work, and the width is to be fourteen inches in the clear; the bottom to be of four and a half inch brick-work, and the curvature thereof to be three inches. The arch is also to be four and a half inch brick-work, having a rise of five inches, and making the height twenty inches in the clear. These drains are to be continued through the fences into the ditches on each side, and when they are under embankments they are to be continued to the extremities of the bottom of the side slopes; they are to be finally backed with good earth well rammed and covered with turf, having the swarded side downwards, upon which good earth is to be laid to the bottom of the road-materials and well rammed.

Should any drains of a different size or strength be wanted for deep embankments, or otherwise, their situation, construction, number, size and value to be determined by the inspector, extra from the contract price.

The water from the surface of the road is to be introduced into the cross-drains by openings or inlets, as shown by the section; they are to be of brick-work ten by fourteen inches in the clear; the side-walls and back-wall of said inlets are to be raised four inches above the side channels of the road, and the wall next said channel is to be kept three inches below, to which the side channel is to be lowered, in a curving form, for conducting the water; they are to be covered with a good sound stone at least twenty-four inches in length, fourteen inches in breadth and two and a half inches in thickness, and covered with good swarded turf, having the swarded side up; the whole of these inlets to be on the outside of the carriage road. The ends of the cross-drains are to be finished with nine-inch brick-work, founded on firm ground as low as the bottom of the inverted arch, to extend to fourteen inches on each side beyond the side-walls, and to be carried up to the height of nine inches above the top of the circular cover. These walls are to be covered with two rows of swarded turf, the lowest with the swarded side down, and the other with

the swarded side up. The foundations of the outer ends of the drains to be secured by strong paving, on a level with the bottom of the drain, extending the whole length of the building, and two and a half feet in breadth; they are to be made strong on the outer sides; where the water enters the drain, the paving is to be so raised on the lower side as to prevent the water from passing it, and at the discharging end the outside course is to be set so deep as to prevent the water from tearing it up. Where a drain is connected with a water-course, wing-walls of nine inches brick-work are to be built in such directions as shall be pointed out by the inspector; they are to be three feet in length, founded as low as the bottom of the drain, and raised to the top of the side-walls, where they are to be covered with swarded turf, having the swarded side up. When water is to be conducted from a ditch, similar wing-walls are to be built, as shall be directed by the inspector. When springs break out on the ground on which the road is to be made, or side slopes of the cuttings, the water is to be conveyed into the ditches or natural water-courses by drains cut to the depth of eighteen inches, laid with well-burnt soughing tiles two and a half inches in width: and where the foundation is insufficient, or the inclination so rapid as to endanger the foundation, they are to be laid on flat tiles, to the points where the water can be carried from the road by open cuts; these cuts are to be made of sufficient dimensions and proper inclinations, as may be directed by the inspector.

Fences.

The fencing is to be constructed as shown in the section. Where the ground is nearly level, or where the cuttings or embankings do not exceed twelve inches, a ditch is to be cut and a bank is to be raised, together occupying a breadth of eight feet.

The ditch is to be cut out of the natural ground, on the field-side of the bank, four feet wide at top and ten inches wide at bottom, and two feet and a half deep; the bank is to be raised by a sod with the green side out, to the height of fourteen inches above the side channel of the carriage-way, and ten inches above the footpath, and it is to be rounded from the ditch with a narrow top to the upper part of the sod, as shown in the section. Two rows of quicksets, twelve plants in the yard, are to be put on the ditch-side of the bank. They are to have good roots, to be two years transplanted, and the best soil out of the ditch is to be used as a bed for them; they are not to be planted sooner than November or later than the end of March. These quicksets are to be protected by two rows of posts and rails, with three rails in height, as shown in the sections; the posts are to be of good sound oak timber, five feet long, and the part above ground is to be five by three inches; the rails are to be of good oak or elm timber, eight feet long and three and a half by one and a half of average dimensions; they are to be at the distances as shown in the elevation, and the two lower rails are to be nearly strait; they are to pass through the mortices fully one inch, to fill the mortices and to be closely joined; prick-posts are to be driven into the ground in the middle spaces, and strongly spiked to the rails.

In the cuttings, the quicksets, as described above, are to be planted at the distance of four feet from the sides of the carriage-road and footpath. A trench, eighteen inches wide and fifteen inches deep, is to be cut out and filled with good vegetable mould, in

the middle of which the quicksets are to be planted; and this is to be particularly attended to. On all embankments, the quicksets are to be planted in a bed prepared as above described. The distance between the rows to be the same as in the cuttings. In both cuttings and embankings, the posts and rails are to be the same as above described, and placed as shown in the sections; one row between the quicksets and the road, and the other row at the top of the cuttings, and near the foot of the embankments. Over the two high embankments of New England and at Kingsbury, a mound seven inches high and fifteen inches wide is to be made on the northern side, and the rails on both sides are to be bushed with strong blackthorn, not more than two inches and a half wide from each other.

Twelve field-gates, with iron hinges and fastenings, and ground-posts, all equal in quality to the best kind in the neighbourhood, are to be finished and erected; at each gate, where there is a declivity from the field to the road, a pavement three feet and a half in width is to be laid in the side-channel, from which a road is to be made into the field eight feet in breadth, and is to be metalled six inches in depth with good gravel, to the extent of seven feet beyond the line of quicksets. Where the road into the field is over a ditch, and the water is to be conveyed past the gateway, a drain of four inches and a half brick-work, ten inches wide and twelve inches deep, arched with brick, is to be built in the bottom of the ditch, above which earth is to be laid, and coated with the depth of materials above specified, to the proper height, in all cases as shall be determined by the inspector.

Kingsbury-lane

Is to be widened to thirty feet, by removing the paling of the Black Lion garden and the pound-fold, and replacing them at the above distance from the brick wall. The present surface of the road is to be raised, and the ground in the field is to be cut down, so as to form an inclined plane from the middle of the present mail-coach road, in a curving direction to the new road, as shown on the plan; the middle eighteen feet is then to be coated with gravel, five inches deep at the sides; and this coating, after being consolidated, after carting over it, is to be covered with six inches in thickness of broken flints, both as described for the new road. The sides of these coatings are to be shouldered with unscreened gravel to the depth of five inches at the sides of the middle materials, and three inches at the sides of the road; and a covering of well-screened gravel is to be superadded, so as to give the elliptical shape specified, and over the middle part one inch and a half of binding gravel is to be laid. The sides of this road in the field are to be fenced as above described.

Bridge over the River Ver.

A bridge of brick-work is to be built over the river Ver, a little above Bow Bridge, opposite the Pond-yards, in the exact situation to be fixed on by the inspector. The dimensions are to be as follows:—the span is to be sixteen feet; height, from surface of low water to springing, to be two feet; rise of arch, four feet; and breadth over the soffit to be thirty-two feet and a half. The abutments to be founded at the depth of two feet below the bed of the river, on platforms of two thicknesses of two-inch planking, laid

crossing each other; and these to be placed upon piles of a length to pass into firm ground, at two feet apart from each other, and to be seven or eight inches diameter; and they are to be secured by pile-planking, five feet in length and three inches thick, along the fronts and sides of the abutments. The thickness of the abutments at the foundations to be six feet, and at the springing of the arch they are to be five feet, with a counterfort in the middle, four feet by three feet. The length of the masonry of these abutments to be thirty-three feet and a half at the foundation, and thirty-two and a half at the springing. The wing-walls to be founded five feet below the surface of the meadow; they are to be twenty feet in length from the face of the abutment, four feet thick at the foundation next the abutment, and three feet at the ends, and they are to be diminished as they ascend to eighteen inches at the top of the arch. The arch is to be eighteen inches brick-work. The parapets are to be three feet and a half high above the finished roadway, and fourteen inches thick, and they are to be coped with circular bricks fourteen inches long and six inches in depth (or eight, if they can be procured), both included in the above height.

The whole of the work to be well bonded, laid in good lime and sand mortar, properly prepared, and executed in a substantial and workmanlike manner, to the satisfaction of the chief engineer for the Parliamentary Commissioners, or of the person employed by him, as inspector.

General Observations.

All the lines are to be marked out by the chief engineer for the Parliamentary Commissioners, or by the person employed by him; and the general formation of the road is to be to his satisfaction. He is also to be satisfied with the solidity of all embankments, before the bottom course of gravel is laid upon them. The preparation of said gravel, and the consolidation of the same, by carting over it, and constantly supplying all the deficiencies therein, are to be approved of by him before the broken top-course of flints is laid upon it. He is also to be satisfied that the top-metal is of proper quality and dimensions, before the binding is laid upon it, and that the cross-drains are properly constructed, and firmly backed, before the turf and earth are laid upon them.

London, 9 July 1823. (signed) *John Easton.*

Appendix (O. 3.)

HEIGHTS taken from High Water at *Holyhead*; commencing at *Holyhead.*

	Feet.
Highest point between the Town and Stanley Sands - - - - - -	47
Near Road to Bodedern - - - - - - - - - - - - -	60
The next summit - - - - - - - - - - - - -	81
At Road to Gwyndû - - - - - - - - - - - - -	180.
At Gwalch-mai Road - - - - - - - - - - - -	223
Cofn-y-Cummwd - - - - - - - - - - - - -	253

STATEMENT of HEIGHTS—*continued.*

	Feet.
Summit east of Maldraeth Marsh	193
Ditto, next Menai Bridge	204
Ditto, between Ferry and Town	166
Bangor Cathedral	56
Llandegai	120
Tyn-y-maes	605
Lake Ogwen	911
Road near half its length	924
Summit east of ditto	957
Opposite Capel Cerig	543
Bettws-y-coed, on flat ground east of ditto	37
Top of Road on Dinas Hill	459
Cernioge Mawr Inn	856
Cerig-y-Druidion	820
Tynant	730
Druid Inn	473
Town of Corwen	444
Owen Glendwr's Hill	430
Rhysgog Hill	530
Woollen Manufactory	325
Llangollen	261
Opposite Pontycysyllte	350
Chirk Village	334
Chirk Bridge	237
Gobowen Village	362
Oswestry Town	428
Queenhead Inn at Canal	292
Nesscliff Village	270
Montford Bridge	190
Hill east of ditto	297
Shelton	258
Welch Bridge, Shrewsbury	174
Corner of Town-hall	200
Centre of English Bridge	172
Ground at Lord Hill's Monument	215
Centre of Atcham Bridge	164
Top of Overley Hill	454
Hay Gate Inn	357
Cock Inn, Watling-street	332
Watling-street Tollgate	322
Summit between it and Ketley	357

STATEMENT of HEIGHTS—*continued.*

	Feet.
Bridge on Shropshire Canal	464
Summit of Snedshill	539
Prior's Lee Toll	425
Bottom of Knowl's Bank	349
Top of ditto	403
Bridge at Shiffnal	270
Top of Windmill Hill	330
Cossford Brook	193
Whiston Cross	309
Summit east of ditto	330
Bonninghall Inn, Homs	264
Top of Summer-house Hill, or Kingwood	485
At the Newport Road	412
Summit east of ditto	458
Village of Wergs	397
Between that and Tattenhall	463
Top of Tattenhall Bank	448
Bridge over the Staffordshire Canal	362
Wolverhampton Market-place	506
Birmingham Canal at Wolverhampton	494
Summit of Bromwich Hill-top	513
Ditto east of Lord Dartmouth's	551
Opposite Mr. Watt's Inn	437
Summit of Soke Hill	450
Hockley Bridge	373
Summit at Hockley Inn	425
Bottom of Snow Hill	380
Top of Bull-street	439
At Bull Ring	419
Top of Bridge Rea River	334
Commencement of Stone Bridge Trust	373
Birmingham and Warwick Canal Bridge	359
Small Heath Toll-bar	426
Bridge on Cole River	342
Road to Yardley	417
Wells Green Brook	318
Hatchford's ditto	303
Cock Inn, Ellendon	360
Law Brook	315
Summit to the eastward	345
Stone Bridge	263
Summit near Meriden	369

STATEMENT of HEIGHTS—*continued.*

	Feet.
Meriden Inn and Academy	343
Summit of Meriden Hill	487
Pickford Brook	354
Summit at ninety-one and a half miles from London	397
Allesley Village	337
Brook east of ditto	295
St. John's Church, Coventry	253
Opposite Coventry Market-place	288
Street	279
At 87 mile stone	244
River Avon Bridge	212
Ryton Village	249
Bottom of Knightlow Hill	249
Top of Hill opposite Red Lion Public-house	330
Ascends gradually along the Ong Avenue to Dunchurch	391
At 76 mile stone	253
Ascend gradually to Willoughby	296
On Bridges over the Oxford Canal	346
Summit east of Braunston, Drayton Hill Toll	543
At Windmill Hill	555
Bottom of Daventry-street	435
Summit of ditto	489
Hollow, east side of Town	447
Summit east of ditto	505
Declines to, opposite Barracks	392
On low ground east side of Weedon	259
On Canal Bridge	320
Summit of first Hill	385
Ditto at Dirt House, now the Angel Inn	447
Descend steep Hill to Goose Bridge	298
Summit east of Forster's Booth	484
Descend to the town of Towcester	296
Summit east of ditto, road to Whittlebury	426
Descend to Cuttle Mill	324
Summit at Plump Park Corner	413
Descend to Potters Pury	303
Summit east of ditto	344
Canal Bridge on Buckingham Bridge	264
Stony Stratford-street	231
Toll-house, Two-mile Ash	349
Canal Bridge at Fenny Stratford	259
Ouse Bridge, east of ditto	241

STATEMENT of HEIGHTS—*continued.*

	Feet.
Church of Little Brickhill	489
Summit at Mr. Duncombe's Gate	526
Opposite Sir Gregory Page's Lodge	376
Toll-house on top of Hill	471
Hockliffe-street	354
Hockliffe Toll above Thames Trinity	359
Summit east of ditto	389
Road bottom of Chalk Hill	316
Ditto on summit of ditto	566
Dunstable-street at Inn	474
At 32 mile-stone, road to Kingsbury	548
Descend to Pack-horse Inn	419
South end of Market-street	392
Bridge east of ditto	378
Top of Flamstead Hill	418
Ely's Wash	335
Ver Bridge, bottom of Redburn-street	291
Tin Mill, formerly a Paper Mill, near 24 m.	282
Ver Old Bridge at St. Alban's	256
Summit of St. Alban's-street	357
Pea Hen Inn, ditto	358
Bottom of Hill, east of ditto	287
At Toll	292
At Green-lane from Shenley	230
Top of Colney Bridge	218
At 17 mile-stone	234
Top of Ridge Hill	372
At the South Mims New Toll	257

APPENDIX (O. 4.)

REPORT respecting RUNCORN BRIDGE, 13th March 1817.

IN consequence of a letter I received from Mr. Fitchett, the Solicitor and Secretary to the Committee for a proposed bridge to be constructed across the river Mersey, at Runcorn, stating it to be the wish of the Select Committee to have a Report from me, respecting the best means of accomplishing this communication, I have paid due attention to the subject, and beg to submit the following as the result of my investigations.

My professional pursuits having afforded me opportunities of being well acquainted with the river Mersey for more than twenty years past, and my attention having been

(early in the year 1814) particularly called to this proposed communication at Runcorn, I am fully aware of its nature and importance.

The points which, as an engineer, I may be expected to discuss, seem to arrange themselves under the following heads; viz.—

1. The practicability of constructing a bridge at the proposed site, and if practicable, what kind of bridge, under all the circumstances connected with the place, is the most eligible.
2. The probable expense and time required to construct a bridge of the form recommended.

1. *Practicability*, &c.

The proposed site is in some respects favourable, it having, on the Cheshire side, a steep bank and a bold rock down to the water's edge; also a projecting point of land of considerable elevation, with a flat rocky shore down to low-water mark, on the Lancashire side; but under low-water mark, the channel (about one thousand feet) is occupied by a mass of sand and mud to a very considerable depth. This last circumstance would render the constructing of any pier or embankments, at this place, if not impracticable, at least very hazardous and expensive; but there are, in my opinion, still more serious objections to introducing any obstructions to the tide-way.

The general economy of this important estuary is maintained by the flowing tide passing with great velocity through a comparatively narrow channel at Liverpool, afterwards spreading over a space from three to four miles in breadth, up to opposite the mouth of the Weaver river; next, rushing with violence through the narrow pass at Runcorn Gap; thence again spreading over a wide space for a considerable distance, and finally passing up the Mersey channel to Warrington; the ebbing-tide performing similar operations in a reversed order. In this manner the whole estuary is adjusted, and the spaces adjacent to the narrows at Liverpool and Runcorn maintained at a proper depth; but even the present powerful reflux, aided by fresh water, is not more than sufficient to repress the great body of sand and mud constantly moved upwards by strong westerly winds, and thereby threatening the entrance to the Weaver navigation, and also that to the Duke's basins; but if the tide was interrupted at Runcorn Gap, and, of course, the reflux destroyed or much lessened, there are strong reasons to expect that the upper end of the whole bay would be filled with sand and mud; if this did take place, not only would the entrances to the Sankey, Old River, the Duke's and Weaver navigations be dangerously affected, but the gradually lessening flux and reflux would unavoidably have a proportionate effect upon the port of Liverpool. Viewing the matter in this light, I should consider myself highly blamable if I did not condemn all projects which go to stop or lessen the tide-way at Runcorn, and point out to those connected with the before-mentioned navigation, and with the perfection of the port of Liverpool, how much they are interested in preserving a free and extensive flux and reflux of the tide.

Being convinced that the true mode of proceeding in this proposed communication at Runcorn is to have in view leaving the tide-way and sundry navigations wholly undisturbed, it follows, that, besides the free admission of the tide-way, it will be necessary

to preserve the road-way across the river at a height sufficient to permit the vessels which navigate the Old River to pass with their masts up, or at sixty feet clear above high water; that the breadth of the channel at low water (one thousand feet) must also be uninterrupted, and that excavations on the Lancashire side below high water must take place, to create a section fully equal to that interrupted by any pier which may be placed on that side, immediately above low-water mark.

Under all these circumstances, it appears evident that all embankments, piers and arches in the main channel are inadmissible, and that passing over one thousand feet, at the height of sixty feet above high water in the lowest place, by any mode requiring centering, though not impracticable, would in this situation be very tedious and expensive; the only remaining way, therefore, is to accomplish a road-way by means of suspension. It is well known that chain-bridges have long been employed with success over very remarkable openings. Major Rennel mentions one, nearly six hundred feet in length, over the Sampoo river in Hindostan; and in a Treatise on Bridges, lately published in America, eight chain-bridges are described, more especially one of two hundred and forty-four feet between the abutments, upon the Merrionack, over which it is said, 'Horses and 'carriages pass freely at any speed, without any perceptible motion of the floors.'

But on considering the matter maturely, it occurred to me that, on the suspending principle, chains are not the most perfect means to be employed; but that the metal should be kept as far as practicable in strait lines, and also have few joinings. In order to proceed with due caution upon this principle, I (during the spring and summer of 1814) made above two hundred experiments upon malleable iron, of from one-twentieth to one inch and a half diameter, and in lengths varying from thirty-one to nine hundred feet. These experiments were made perpendicularly, horizontally, and with different degrees of curvature.

Extract from Report of 1814.

'The inquiry respecting the tenacity of malleable iron was commenced by proving 'what force would tear asunder, lengthways, pieces of iron from one and a half inch to 'one-twentieth of an inch in diameter. The experiments upon the first or larger diameters 'were performed with great accuracy with an excellent hydrostatic machine constructed by 'Mr. Fuller, at Mr. Brunton's patent chain-cable manufactory, Commercial-road, London; 'those upon the smaller diameters were made by weights attached perpendicularly and 'sundry times repeated. Having ascertained their powers when suspended perpendicularly, 'I next made experiments upon different diameters from one-tenth to one-twentieth of an 'inch, drawn horizontally, and with different degrees of curvature; all these were done 'between points nine hundred, two hundred and twenty-five, one hundred and forty, one 'hundred and thirty-one and a half feet apart, and repeated sundry times upon the different 'distances and diameters. The number of experiments in all amounts to above two 'hundred.

'In the experiments made upon one-tenth of an inch and under, the wire was drawn over 'pulleys; sometimes both ends were fixed, and sometimes one end only; the other having 'weights attached perpendicularly to show their effects when compared with those loaded 'upon the curved part of the wire; these last were disposed at the one-fourth, one-half and

'three-fourth divisions of the distance over which it was stretched. Having completed 'these experiments, I next proved what force by a blow would break the wire when 'stretched nearly horizontal and at different curvatures, which was done by dropping 'weights from a given height. The several wires upon which these experiments were 'made were weighed, and the weight of one hundred feet in length of each noted.

'The results of these experiments were, that a bar of good malleable charcoal iron one 'inch square will suspend twenty-seven tons, and that an iron wire one-tenth of an inch 'diameter (one hundred feet in length weighing three pounds three ounces) will suspend 'seven hundred pounds; and that the latter, with a curvature or versed sine of one-fiftieth 'part of the chord line, will support one-tenth part of the weight suspended perpendi-'cularly, when disposed equally at one-fourth, one-half and three-fourths of its length; 'and with a curvature of one-twentieth of the chord, it will bear one-third of the aforesaid 'perpendicular weight, disposed in a similar way. Experiments upon the other diameters 'correspond sufficiently, and it was found that increasing the distance only varied the 'effect by the difference of the weight of metal contained in the wire employed.

'A wire one-tenth of an inch in diameter, drawn very tight between points thirty-one 'feet six inches apart, resisted the impulse of a twenty-pound weight falling from a height 'of seven feet nine inches. Several other experiments were tried with lesser weights upon 'this and smaller wires:'—[for details of these experiments, see the end of this article.]

'From these experiments I had reason to be satisfied that English iron made with wood 'charcoal had sufficient tenacity to bear itself, and a portion to spare equal to the purposes 'of a bridge across an opening of one thousand feet, and therefore considered myself 'justified in proceeding to form designs.'

These experiments upon the elementary parts, having fully confirmed my expectation, justified my forming the design which accompanies this Report. Here all the perpendicular suspenders, cross-ties and diagonal braces are composed of strait square bars of malleable charcoal iron, kept in their proper direction by others. All the great suspending cables are composed of small iron rods, of such dimensions as to ensure perfect flexibility. These parts are so distributed as to afford two driving-ways of twelve feet each, with a footpath or horse-way of six feet between them: this also affords four points of suspension in the breadth of the bridge. All the essential parts being so disposed as to admit of their being occasionally painted, or covered with some coating substance which shall effectually protect the iron from the action of the atmosphere and the whole being united so as to afford an opportunity of each part being taken out and renewed separately, without materially affecting the strength of the bridge, the structure may by these means, for any length of time, be preserved in a perfect state.

After many experiments, I have also succeeded in forming a roadway, independent of timber, which is impervious to water, has a perfect elasticity, and appears indestructible.

'Having completed the framing and abutments, I proceed to describe how a roadway 'is to be formed, in order to obtain elasticity, firmness and durability. 1. Over the whole 'roadway bed, a layer of tin plates is to be fixed to the framings. 2. Upon the tin a

Extract from Report of 1814.

'coating, or layer of composition, consisting of coal tar and Parker's British cement, with 'a small portion of oakum, mixed into the consistence of a thick mortar, is to be spread 'about one inch in thickness. 3. Over this a stratum of wool, mixed with vegetable 'tar, is to be laid about four inches in thickness when compressed. 4. Over the wool 'there is to be laid a stratum of oakum, mixed with vegetable tar and pounded charcoal, 'also four inches thick when compressed. 5. The uppermost stratum of four inches is 'to be of the same composition as laid upon the tin. This composition will fulfil the 'conditions required, and be quite impervious to water; it may be convenient to spread 'a bed of iron-forge cinders or slag, about two inches in thickness, upon the surface of 'the roadway. I have made sundry experiments upon this sort of roadway, and find it 'answers my expectations; the specimens are sufficient evidence of its efficacy.'

In order to elevate the roadway to the required height of sixty feet above high-water mark, it will, by the drawing, be seen that I have, at low-water mark, on each shore, constructed a stone building of a pyramidal shape; it is of course hollow, with cross-walls, and gateways for the roadways; all the suspending cables pass over these, extend five hundred feet farther, and are in all respects each similar to one-half the principal arch, and form its counterpoise; these also serve to bring the roadway down to a moderate height of abutments and embankments on each side of the river.

The plan here described appeared to me, upon the most deliberate consideration, to be the most practicable and economical mode in which, (under all circumstances) a communication could be accomplished; and it might be done without interrupting or injuring the navigation.

After this design was completed, I constructed a model of fifty feet in length, and one twelve-hundredth part of the strength of the intended bridge, and although composed of wire only, and of course without proper joints or braces, it bore three thousand pounds without any symptom of its parts being deranged.

Thus far I proceeded in 1814; I was perfectly convinced of the practicability of the scheme, and am now satisfied I went farther than necessary in the quantity of material employed, and also as to sundry precautions in forming the plan, but I was willing to err on the safe side.

Having hitherto spoken of the scheme generally, and the progress I had made during the year 1814, I have now to advert to the sundry plans which have been furnished to the Committee, and submitted to my consideration by Mr. Fitchett. From the foregoing discussion it will be evident, that any plan formed upon a principle different from that of suspension is, in my opinion, quite inapplicable. In regard to all those which fall under this description, it therefore seems unnecessary to enter upon any investigation of their comparative merits; and as the same observations apply to those on suspending principles, which are constructed with chains, it follows that, of all the plans submitted to me by Mr. Fitchett, it is that produced by Captain Brown only which corresponds to the principle adopted by me in 1814; that is to say, suspension by malleable charcoal iron,

preserved, as nearly as practicable, in strait lines, and having a degree of flexibility, to avoid cross-strains.

His perpendicular suspenders, cross-ties and diagonal braces correspond precisely with mine. His main suspending-lines of the upper curve, instead of being composed of a number of flexible rods, as in mine, consisted of one rod or bar, malleable iron, united by firelocks. From four of these it was proposed that the whole structure should be suspended; and according to this, Captain Brown had constructed a model, one hundred feet in length, at his patent chain-cable manufactory, opposite Deptford. Your solicitor and I examined this model, and drove a hackney-coach over it. We afterwards had a full conference with Captain Brown in London, in the course of which he very distinctly explained his ideas, and they, in general, very nearly corresponded with my own. I then communicated to him the whole of my operations in 1814, which have already been detailed in this Report, and showed him the drawing I had then made. These communications first disclosed to him the true situation in which a bridge was required, and convinced him of the propriety of having one great opening of one thousand feet, and one of five hundred feet, on each side. He was also convinced of the propriety of having, at least, eight rods or bars in the great suspending-line of the upper curve; (I prefer still more;) and likewise, instead of throwing the whole bearing upon them, as he had formerly proposed, that a great advantage may be derived by forming the roadway, as in my plan, in a curve of one-fiftieth part of the chord-line, thereby gaining additional strength, instead of leaving it merely a dead weight. His roadway is very ingeniously contrived of timber, in shape of the cover of a ship's hatchway, which, though certainly not so durable, is much lighter and cheaper than that which I had composed; and as the flooring may be so contrived as to be in future, if necessary, replaced by mine, I think it had better, in the first instance, be adopted, with, perhaps, a few inches of mine upon the top of the timber. I pointed out to Captain Brown the manner in which his roadway should be supported, tied and braced.

This new view of the subject having deranged the proposals he had laid before the Committee, I furnished him with an outline of my plan, in order to enable him to fill it up, and estimate the expense of the iron-work, under the sundry regulations upon which we had agreed.

Mr. Fitchett has received the said outline, with Captain Brown's general notions as to the iron-work and expense. This will be laid before the Committee; but he still, in my opinion, requires more local information and discussion to enable him to give a correct estimate.

Having now discussed what relates to the plan, I beg leave to repeat my perfect conviction of its practicability. I am satisfied it is the only one which, under all the circumstances of the case, ought to be adopted; by it this important and long wished-for communication would be accomplished, without interruption or injury to any of the navigations upon or connected with this estuary; and in this view, it cannot fail of meeting with the approbation and support of those interested in them, who will thereby for ever

exclude all other projects, which would unavoidably prove pernicious. I shall therefore now proceed to consider the second head; viz.

2. *Probable Expense, and Time of Performance.*

Many circumstances seem, at the present time, favourable to this proposed improvement. The price of iron is unusually low; many excellent stone-quarries have been opened in the immediate neighbourhood; the price of labour of all kinds is also much under what it has been for many years past; and there is water-communication in all directions to the very spot. I have, in forming calculations, proceeded upon what I consider the extreme of what will be required in each department.

Not having made any surveys of the roads, I can at present form no correct estimate of this part of the improvement.

With regard to the time of performance, I am of opinion that the whole might be completed in three years from the time of commencement, perhaps in less.

ESTIMATE.

	£.	£.
Masonry in pyramids and abutments=25,264 cube yards, at 15/	18,948	
Ditto - - in retaining-walls - 4,000 - ditto - at 12/	2,400	
Parapets upon - - ditto - - - - - - - - -	250	
Iron-work in curbing and ties - - - - - - -	2,000	
		23,598
Malleable iron-work and painting, 1,423 tons - at £.25	35,575	
Cast-iron work - - - - - - - - - - - -	2,000	
		37,575
Roadway over the bridge, 60,000 cube feet - - at 5/	- -	15,000
Earth-work in abutments, 20,000 cube yards - - at 1/	- -	1,000
TOTAL for BRIDGE - - - - -	£.	77,173
Ten per cent. contingencies - - -	-	7,717
	£.	84,890

According to Captain *Brown*.

POWER OF SUSPENSION:

		In. In. In. Tons.	
Main cables - -	-	No. 8 of $5 \times 1\frac{1}{2} = 60 \times 27 = \frac{1,620}{3}$	=540 tons.
Cables below roadway	-	8 of $5 \times 1\frac{1}{2} = 60 \times 27 = \frac{1,620}{10}$	=160 -
			700 tons

Weight of Iron:

	In. In. In.	
Main cables - - - - -	$5 \times 1\frac{1}{2} = 7\frac{1}{2} \times 16 \times 12 = \frac{1,440}{4}$	$= 360$ lbs.
Diagonals - - - - - -	$5 \times 1\frac{1}{2} = 7\frac{1}{2} \times 2 \times 12 = \frac{180}{4}$	$= 45$

```
                 405
                2100
                 405
                810
2,240) 850500 (379 tons.
       6720
       17850
       15680
        21700
```

Suspending rods, ties and braces - - - - - - say 316

695

POWERS OF SUSPENSION:

	In. Tons.	Tons.
Section of bars in upper curve of $\frac{1}{20}$th the chord line - -	$216 \times 27 = \frac{5,832}{3}$	$= 1,944$
Ditto - ditto in lower ditto, of $\frac{1}{30}$th the chord line - -	$164 \times 27 = \frac{4,428}{10}$	$= 442$
Suspending Power - -		$= 2,386$ tons.

Weight to be suspended:

	Tons.
Roadway - - - - - - - - - - - - - -	700
Iron braces, &c. - - - - - - - - - - - - -	370
Ten waggons, &c. - - - - - - - - - - - -	100
Total Weight to suspend - - -	1,170 tons
Surplus Power - - -	1,216 tons

Sir, London, July 1817.

I have, by the same mail-coach by which this letter will travel, sent the drawings, report and estimate of Runcorn Bridge; also a paper containing the details and calculations upon which the designs are constructed, and the estimations are founded. I send these last, in order to enable such of the Committee as are accustomed to making calculations to satisfy their minds as to the practicability, stability and expense.

Although the Committee may consider themselves bound to investigate these matters, I much doubt the propriety of making calculations and prices public, even the prices, &c., stated in the general estimate, because, in case the bridge is proceeded with, these data

will but too much influence persons who may be disposed to give in proposals for different parts of the work.

The Committee will also, I trust, perceive that I have spared no pains to render every part of the process perfectly explicit and clear, with the most minute details; and that, in submitting to their inspection and examination my plans, reports and estimates, I rely upon their honour and delicacy that they shall not be submitted for the opinion of improper persons who may be naturally inclined, from competition or other private feeling, to prefer some other plans, or throw doubts upon mine, without having gone through the same series of experiments and labour which I have bestowed upon this object during a period of four years, the whole result of which has tended only to confirm my conviction of the practicability and safety of this plan, which depends not on theory, but wholly on experiments, frequently repeated, some on lengths nearly equal to that of the largest proposed opening.

In forming the estimation of the expense, I have taken pains to ascertain the quantities of each sort of work, and as the price of each is separately stated, the Land Committee will judge whether or not it is proper. For instance, the fluctuating price of iron renders its rate somewhat uncertain.

I have attentively reconsidered all the circumstances respecting the plan of a bridge for the river Mersey, at Runcorn, which I had the honour of submitting to the Committee; I have also repeated sundry experiments upon the tenacity of malleable iron; all these have served to confirm my conviction of the practicability of constructing a bridge there upon the principle of suspension, and of the openings stated in the before-mentioned plan. With regard to the great suspending cables, the further consideration I have been able to give this important part of the design has likewise satisfied me that there is no mode preferable to that which originally occurred to me; their shape may be seen among the delineations of the separate parts, and their description will be found in another part of this Report. In order as much as possible to lessen the expense, I have turned my attention to modifying the plan, and with this view, I have reduced the breadth of the bridge from thirty feet to twenty-five feet, that is to say, ten feet for each carriage-way, and five feet for the footpath in the middle; this contraction of width, but still preserving four suspending points, has induced me to reject most of the iron-work which composed the former roadway, and in its place substitute timber, as being not only much cheaper, but lighter; this produces a corresponding change upon the suspending cables and perpendicular rods. The making of the roadway in strait instead of curved lines, produces also a reduction in height of the pyramids, and of course in the dimensions of the walls. By making the roadway, of the sides or five hundred feet openings, to descend at the rate of one in twenty-two, the abutments and approaches are brought to a more moderate height. The effect of all these circumstances will be evident by the calculations and estimated expense.

In order to determine the proper section for the suspending cables, it is necessary to ascertain the weight to be suspended, also its position. The weight, it will be evident,

consists of the timber and iron-work of which the roadway is composed, with the iron rods by which it is suspended to the cables, also the side protecting railings, consisting of four longitudinal horizontal iron bars, four inches by one inch, with cross horizontal connecting bars one inch square. These bars are intended more as a frame to support the wooden beams until adjusted in their places, than as affording much strength. Upon these bars, at the distance of every five feet, are placed two transverse beams, each nine inches by six inches, between which the suspending rods are passed, and under which they are secured by plates and wedges; upon these transverse beams are laid twenty-three longitudinal beams, each six inches square, that is, two along each outer edge of the roadway, and two along each side of the footway; between each of these parts the suspending rods are likewise passed. Along each carriage-way three beams, each six inches square, are laid under the track of each wheel, one of the same size under where the horses will tread, and one in the middle of the footway. Across the longitudinal beams are laid two rows of three-inch planking, so as the upper shall cover the lower joints, and the whole are secured to the beams by screw-bolts passing down in the middle of each carriage-way, and also the footpath, thus communicating the pressure which may be placed on any given point over the whole breadth and to a considerable distance along the roadway. These timbers are also disposed so as to admit of being taken out and replaced. The carriage wheels are kept in the proper track by guards, and over each carriage-way there is a covering of two-inch oak plank, intended as the wearing surface, which may be occasionally renewed at a small expense.

Along each side of the bridge I have, by way of protection, introduced diagonal braces to the height of seven feet above the roadway, and along the inside of these have fixed wire grating. This protecting railing is made seven feet high, in order to do away any apprehension which it is alleged timid persons might feel at passing seventy feet above the water; but a much lower railing is found quite sufficient to remove all alarm or idea of danger at Sunderland Bridge, although its roadway, instead of seventy feet, is elevated one hundred feet above the tideway.

From my separate paper of calculations it will be seen, that the roadway in one thousand feet of length consists of—

	Tons.	lbs.
Fir timber - - - - - - - - - - - -	430	920
Oak ditto - - - - - - - - - - - -	44	1,440
Iron-work connected with roadway, also in suspending rods and railing - - - - - - - - -	98	428
Weight allowed at one time upon one thousand feet - -	100	–
To be suspended upon one thousand feet in length -	673	548

Say 700 tons.

From many experiments by myself and others, it has been ascertained that a bar of good English malleable iron, one inch square, will suspend from twenty-seven to thirty tons before it breaks, and that it bears from fifteen to sixteen tons before it begins to be

extended in length. By my experiments it was ascertained that with a curvature of one-twentieth of the length, malleable iron, besides its own weight, sustained one-third of what broke it perpendicularly. An inch bar would therefore bear one-third of fifteen tons, without deranging its parts; but in order to be considerably within its power, I have only assumed that one inch square of section shall be loaded with four tons; therefore, taking the whole weight to be suspended in one thousand feet, or the greatest opening, that is $\frac{700}{4}$ tons = one hundred and seventy-five inches, but as I propose that there shall be sixteen cables, that is, four on each suspending line, $\frac{175}{16}$ gives eleven square inches, nearly, for the section of each cable.

I have already in this Report stated, that further consideration and discussion have strengthened my original idea with regard to the mode of constructing the main suspending cables, that is, composing them of a number of small flexible iron rods, that when put in their proper situation shall be all drawn lengthwise. I have combined thirty-six rods of half an inch square, which together make three inches square; upon each side of these I have placed an iron segment, which nearly, though not wholly, covers each side; these segments, complete the circular cable, cover all the joints of the half-inch bars, and afford the means of compressing them firmly; these together afford a section of twelve feet five inches, being about one-eighth part more than the before-mentioned eleven inches; so that in this view of the subject, the provision of suspensive power appears more than ample, which, in a case of this kind, should, in my opinion, be most evident. In constructing the cable, there is little reason to doubt but that the half-inch rods might all be formed with great correctness, so as to fit each other with all the desired accuracy, but in the specimen I have got made, I have introduced a mixture of bees-wax and resin, which has effectually pervaded any insterstice, uniting the whole in one mass perfectly impervious to water; the surface of the cable is then covered with flannel previously saturated in the before-mentioned composition, and then the whole is firmly wrapped round with wire, which imbeds its lower half in the moistened flannel, and leaves the outer surface only to be protected from the action of the atmosphere, which, it must be allowed, is no very uncertain or difficult operation. This wire wrapping effectually binds all the parts of the cable into one firm mass, which is further secured at the distance of every five feet by the bucklings which connect the suspending rods with the main cables. Thus connected and bound together, the parts might be considered safe, from the great extent of surface exposed to friction, but I do not mean to rely upon that alone, but propose welding each half-inch bar, and also the four covering segments, so that each shall constitute one filament the whole length of the bridge. Each cable may be removed and replaced singly, without materially affecting the permanency of the bridge. Each extremity of these cables is extended along the abutment walls for about one hundred feet, and in that distance secured in cast-iron frames firmly connected by wrought-iron ties, with such a mass of masonry as shall be more than sufficient to resist the strain to which these cables are exposed.

For the particular calculations respecting the quantity of materials contained in the main cables, pyramids, abutments and retaining-walls, I shall again refer to the separate

paper which accompanies this, and here merely give the results by way of estimate of the expense.

ESTIMATE.

		£.	s.	d.
12,049 4=48,196 cubic feet fir timber in roadway - -	at 4s.	9,639	4	–
4,000 - - oak - - ditto - -	6s.	1,200	–	–
197 tons of malleable iron in roadway, suspending rods, couplings, railings, &c.	£. 25	4,925	–	–
631 tons in main cables, &c. - - -	£. 25	15,775	–	–
28 ditto in ties in pyramids and abutments -	£. 20	560	–	–
132 ditto cast-iron frames upon top of pyramids and upon abutments - -	£. 12	1,584	–	–
Cement for cables - - - - - -		1,800	–	–
17,518 cubic yards of masonry in pyramids -	18s.	15,766	4	–
1,784 - ditto - - - - - - abutments -	18s.	1,605	12	–
1,370 - ditto - - - - - - retaining-walls,	15s.	1,027	10	–
20,105 - ditto - - earthen-work approaches -	1s.	1,005	5	–
Painting the iron-work - - - - - -		1,000	–	–
Making a temporary lock-bridge over pyramid		1,000	–	–
Allow ten per cent. contingencies - - -		5,678	–	–
TOTAL - - -	£.	62,565	15	–

To the foregoing discussion, it does not occur to me that much need be added, excepting perhaps something respecting the mode of putting the main cables into their places. That which I have at present conceived to be most advisable is, first to construct the pyramids and abutments, with the cast-iron framings upon them; then, over these to draw such a quantity of iron wire as may be formed into a foot-bridge, along which the first cables may be conducted and arranged, and which foot-bridge may afterwards be moved along the tops of the pyramids, until the whole of the cables and suspending rods have been adjusted in their places.

Having now gone through the most minute details respecting this plan, the Committee to whom this Report is submitted cannot but be sensible that the whole has been cautiously founded upon facts, arising out of experiments made during a period of four years, in which I had bestowed much thought and labour on this important object, the whole result of which has tended only to confirm my conviction of the practicability and safety of this plan, which depends not on theory, but entirely on experiments frequently repeated, some on lengths nearly equal to that of the largest proposed opening. And on similar experiments and attention being repeated by any other person, I cannot entertain a doubt but that his mind, however dubious in the first instance, by reason of the novelty and magnitude of the plan, will become equally satisfied with my own.*

* The details of these experiments are given at the end of this article.

DETAILED CALCULATIONS respecting the Quantity of MATERIALS contained in the ROADWAY, MAIN CABLES, PYRAMIDS, ABUTMENTS and RETAINING WALLS.

	No.	Ft. In.	Ft. In.	Ft. In.	Cub. Ft.	Tons.	lbs.	Tons.	lbs.
To be suspended—FIR TIMBER PLATFORM for ROADWAY:									
Lower transverse beams - -	200 ×	26 0 ×	0 9	× 0 6	= 1,987				
Longitudinal ditto - - -	23 ×	500 0 ×	0 6	× 0 6	= 2,875				
Lower planking - - - -		500 0 ×	26 6	× 0 3	= 3,312				
Upper ditto - - - -		500 0 ×	27 0	× 0 3	= 3,375				
Guards to sides - - - -	4 ×	500 0 ×	0 6	× 0 6	= 500				
At 40 lbs. per foot cubic - - - - - -					12,049 =	215	460		
This being in 500 feet in length, multiply by - - - - - -							2		
Which gives in 1,000 feet in length - - - - - - - - - -						430	920	430	920
Oak timber planking to carriage-way - - - - -	2 ×	500 0 ×	6 0	× 0 2	= 1,000	22	720		
At 50 lbs. per foot cubic - - - - - - - - -							2		
						44	1,440	44	1,440
IRON-WORK in ROADWAY, and SUSPENDING BARS, RAILING, &c.									
Longitudinal horizontal bars -	4 ×	500 0 ×	0 4	× 0 1	= 55 7				
Cross - - ditto - - -	100 ×	25 6 ×	0 1	× 0 1	= 17 8				
Suspending rods - - -		11,240 ×	0 0¾	× 0 0¾	= 43 11				
Couplings - - - - - {	400 ×	3 0 ×	0 2	× 0 1	= 16 8				
	400 ×	6 0 ×	0 10	× 2 × ½	= 14 0				
Bars, 7 feet above roadway - -	400 ×	5 6 ×	0 0¾	× 0 1½	= 17 2				
Diagonal braces in railing - -	800 ×	9 0 ×	0 0¾	× 0 0¾	= 28 1				
Wedges at bottom of suspenders -	400 ×	0 9 ×	0 4½	× 0 0¼	= 2 4				
Collars - - - - - -	400 ×	1 1 ×	0 1½	× 0 0½	= 2 3				
Wedges - - - - - -	800 ×	0 4 ×	0 1½	× 0 0¼	= 0 8				
Collars - - - - - -	400 ×	1 4 ×	0 1½	× 0 0½	= 2 9				
Ditto - - - - - -	1,600 ×	0 4 ×	0 1½	× 0 0¼	= 1 4				
Bolts, &c. middle of roadways -	200 ×	2 0 ×	0 0¾	× 0 0¾	= 1 7				
Ditto - - - - - -	200 ×	0 2 ×	2 0	× 0 0¾	= 0 4				
Plates for ditto - - - -	200 ×	0 6 ×	3 0	× 1 0	= 2 1				
Plates to guard-timbers - -	2,000 ×	1 0 ×	0 0⅛		= 21 0				
Wire to railing of sides - -	- -	- -	- -	- . -	4 0				
					231 5				
At per cubic foot - - - - - - - - - -					432 lbs.				
					99,974 lbs.				
Spikes for planking - - - 30,000 - - - - - - - -					10,000				
					109,074 =	49	214		
This being in 500 feet in length, multiply by - - - - - -							2		
Which gives in 1,000 feet - - - - - - - - - - - - - -						98	428		
Allow upon the 1,000 feet as equal to 10 loaded waggons, say - - - - - - - - - - - - -						100	0		
						198	428	198	428
Total to be suspended in 1,000 feet - - - - - - -								673	548

Say 700 tons: allowing at the rate of 4 tons upon every square inch of section in the 16 cables:

$$\frac{700}{4} = \frac{175}{16} = 10{\cdot}9 \text{ square inches for each cable: say 11 inches.}$$

Cables.	No.	Feet.	Feet.	Ft. In.	Tons.	lbs.	Tons.	Cwt.
Main cables	16 ×	2,300 ×	12	× 12 5 ÷	4 ÷	2,240 =	595	10
Diagonal ditto	2 ×	2,200 ×	12	× 6 0 ÷	4 ÷	2,240 =	35	7
							630	17

Pyramids.	Feet.	Feet.	Feet.	Cubic Feet.	
Outer walls to first offset	316 ×	16 ×	8·6	= 42,976	
Ditto to second ditto	284 ×	10 ×	7	= 19,880	
Ditto to top	168 ×	116 ×	4·6	= 87,696	
Interior walls up to roadway	135 ×	86 ×	3	= 34,830	
	98 ×	86 ×	3	= 25,284	
Centre arch and spandrils	64 ×	11 ×	10	= 7,040	
Side ditto	128 ×	$6\frac{1}{2}$ ×	$4\frac{1}{2}$	= 3,744	
Arch and spandrils under roadway	41 ×	12 ×	12	= 5,904	
Angles between inner and outer walls	82 ×	6 ×	$2\frac{1}{2}$	= 1,230	
Inner cross-walls from roadway to top	194 ×	$14\frac{1}{2}$ ×	2	= 5,626	
Arches for carriage-ways, with spandrils	18 ×	4 ×	19	= 1,368	
Masonry over footpath archway	19 ×	$4\frac{1}{2}$ ×	3	= 256	
Ditto between carriage-ways and outer-walls	19 ×	9 ×	3	= 513	
Ditto between walls and top of pyramid	10 ×	5 ×	3	= 150	
				3) 236,497	
				9) 78,832	
				8,759	Cubic yards in one pyramid.
				× 2	
				17,518	Ditto in both pyramids.

Abutments.				Cubic Feet.	
Abutment, Cheshire side.					
Front and side walls	120 ×	15 ×	6	= 10,800	
Inner middle-walls	50 ×	15 ×	7	= 5,250	
Abutment, Lancashire side.					
Front and side walls	120 ×	30 ×	6	= 21,600	
Inner middle-walls	50 ×	30 ×	7	= 10,500	
				3) 48,150	
				9) 16,050	
				1,784	Cubic yards in both abutments.

	Feet.	Feet.	Inches.	Cubic Feet.	Tons. lbs.
Cast-iron frames on top of pyramids and abutments	27 ×	10 ×	6 =	135 =	26 80
					× 2
In the two pyramids	-	-	-	-	52 160
Allow 80 frames of 1 ton each upon abutments	-	-	-	-	80
				say -	132 Tons.

	Feet.	Ft. In.	Ft. In.	Cubic Feet.	Tons. lbs.
Iron-ties in pyramids and abutments - - - - -	1,539 ×	0·3 ×	0·1 =	518 =	6 420
				say - -	7
					2
In the two pyramids - - -	- - -	- -	- -	-	14
Allow an equal quantity for abutments - - - - -	- - -	- -	- -	-	14
					28 Tons.

	Feet.	Feet.	Feet.	Cubic Feet.	
Retaining-walls.					
Cheshire side - - - -	200 ×	15 ×	5 =	15,000	
Lancashire side - - - -	200 ×	20 ×	5½ =	22,000	
				3) 37,000	
				9) 12,333	
In the two sides - - - -	- -	- -	-	1,370	Cubic Yards.

EXPERIMENTS on the Direct and Transverse Resistance of Iron Wire, of different Lengths and Dimensions, by *Thomas Telford*, Esq., F. R. S. E., &c.

Extracted from Essay on the Strength of Timber and Iron.
By Peter Barlow, F. R. S. *Edition* 1824.

The following course of experiments was instituted with a particular object, viz. the obtaining of data connected with the erection of an iron hanging-bridge over the river Mersey, at Runcorn, near Liverpool; which, from the nature of the navigation, was to consist of only three spans or openings, the centre one of one thousand feet, and the two others five hundred feet each, making the entire length two thousand feet. It was also necessary to keep the intrados seventy feet above high-water mark. An arch-bridge, under these circumstances, is conceived to be wholly impracticable; and both courage and genius were requisite to conceive any practicable construction. Mr. Telford proposed, however, an iron hanging-bridge, to consist of sixteen cables or bars, each formed of thirty-six square half-inch iron bars, and the segments of cylinders proper for forming them into one immense cylindrical iron cable, which, in its whole length, including the fixings on shore, would be nearly half a mile, and about four inches and a quarter diameter; that is, the diagonal of the square section of the thirty-six half-inch bars will be equal to the square-root of $18 = 4{\cdot}24$ inches; and this diagonal will obviously be the same as the diameter of the cylinder, after the segments above mentioned are applied to the four sides of the square prism.

Each of these half-inch bars, as well as the four segments, were to have been welded into one length; and being well secured with bucklings at every five feet, and wrapped

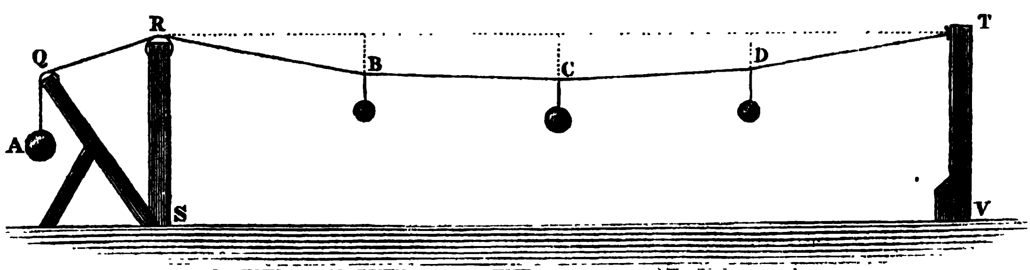
in flannel, well saturated with a composition of rosin and bees-wax, to preserve them from the weather, they were to have been further bound together with wire, of about one-tenth part of an inch in diameter, forming one immense iron cable of the entire length; and from sixteen of these cables, the roadways, which were to consist of two for the passing and repassing of carriages, and a centre one for foot-passengers, were to be suspended. The two principal supports for forming the centre span were intended to be about one hundred and forty feet in height, and the deflection of the centre of the inverted arch, or catenary, one-twentieth of the opening, viz. fifty feet; and the two side-spans to consist of two semi-catenaries, which were originally designed to be of the same curvature as the principal centre one, viz. the lowest point of the centre catenary was proposed to be exactly in the same horizontal line as the two extremities of the side-openings, which would have effectually relieved the two principal supports from any horizontal draw, or of any tendency to overturn; but some slight modification of this plan was afterwards made, for the sake of reducing the expense, which would bring the extremities of the side semi-catenaries lower than the lowest point of the centre one.

An undertaking of such immense magnitude, so perfectly original, and which, when completed, will perhaps be one of the most singular works of art that any age or nation ever produced, ought not to be attempted without the best data that could possibly be obtained, relative to the strength of the proposed materials, under all the variety of strains to which they are likely to be exposed; and the following course of experiments were therefore made, as before stated, with this particular view.

In order to comprehend the tabulated results, it will be necessary to explain the apparatus with which the experiments were made. These are presented in the annexed Figure.

Here R S, T V, represent the supporting pillars upon which the wire was extended; Q S, another prop, over which the wire passed; being placed at such an angle as made it coincide with the direction of the resultant of the vertical and horizontal tensions, in order to prevent any strains upon the other support, R S.

A, B, C, D, represent the places of the several weights with which the wire was loaded; C being in the centre of the length, and B and D at one quarter of the length from each end; and the deflections from the horizontal line R T were measured at these points, as the different weights were applied.



Experiment, No. 1.

Distance of the Props, 100 feet; weight of 100 feet of wire, 29½ ounces; diameter, rather more than $\frac{6}{70}$ths of an inch; and it broke, when suspended vertically, at a medium of different trials, with 531 lbs.

Weight at A, including the Wire Q A.	Weight at B.	Weight at C.	Weight at D.	Deflection at B.	Deflection at C.	Deflection at D.	REMARKS.
lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	ft. in.	ft. in.	ft. in.	
5 6½	- -	- -	- -	- -	4 10	- -	Deflections at B and D not taken.
10 5	- -	- -	- -	- -	2 11½	- -	
30 5⅕	- -	- -	- -	- -	– 10½	- -	
Ditto -	- -	1 –½	- -	- -	1 8	- -	
Ditto -	- -	2 –½	- -	- -	2 7	- -	The weight at C being taken off the deflection, became 11 inches.
Ditto -	- -	5 –½	- -	- -	4 11	- -	
176 –	5 –	30 4	5 –	2 1	4 6½	2 1	Raised weight A, 1 inch.
Ditto -	9 –	30 4	5 –	2 5½	4 10¼	2 2½	
226 –	9 –	56 –	5 –	3 11	7 10½	3 7½	
286 –	9 –	56 –	5 –	2 8¾	5 11½	2 6½	
342 –	9 –	56 –	5 –	2 3½	5 –¾	2 1¾	
Ditto -	9 –	66 –	5 –	2 5	5 4½	2 3¼	
Ditto -	9 –	72 –	5 –	2 7	5 9⅛	2 5¼	
Ditto -	9 –	77 –	5 –	2 7	5 10	2 5¼	
Ditto -	9 –	81 –	5 –	2 9¾	6 4¾	2 8	
Ditto -	9 –	87 –	5 –	2 10¼	6 6¼	2 8½	
Ditto -	15 –	71 –	15 –	2 11¾	6 3¾	2 11¾	
402 –	15 –	71 –	15 –	2 8¼	5 8¾	2 8¼	Broke, after sustaining these weights for a short time.
402 –	30 –	56 –	30 –	- -	- -	- -	

Experiment, No. 2.

Distance of the Props, 31 feet 6 inches; the same specimen of wire as in Experiment, No. 1, but had not been before used; the two ends of the wire in this Experiment were fixed, after drawing it as tight as possible; viz. to within less than one-eighth of an inch of a horizontal line, and the weights applied only in the centre.

End at R and T fixed.	Weight at B.	Weight at C.	Weight at D.	Deflection at B.	Deflection at C.	Deflection at D.	REMARKS.
		lbs.			ft. in.		
Fixed -	- -	10½	- -	- -	– 2·83	—	
Ditto -	- -	20½	- -	- -	– 5·5	—	
Ditto -	- -	30½	- -	- -	– 7·75	—	
Ditto -	- -	40½	- -	- -	– 10·	—	
Ditto -	- -	50½	- -	- -	1 –	—	
Ditto -	- -	60½	- -	- -	1 1·75	—	
Ditto -	- -	70½	- -	- -	1 3·5	—	
Ditto -	- -	80½	- -	- -	1 5·	—	
Ditto -	- -	90½	- -	- -	1 6·5	—	
Ditto -	- -	100½	- -	- -	1 8·	—	
Ditto -	- -	110½	- -	- -	1 9·75	—	
Ditto -	- -	120½	- -	- -	1 10·75	—	Just bore the last weight, and then broke.
Ditto -	- -	130½	- -	- -	- -	- -	

Experiment, No. 3.

Distance of Props, 100 feet; Diameter, $\frac{1}{10}$th of an inch; Weight of 100 feet = 2 lbs. 9 oz.; Bore, vertically, 736 lbs., but broke with 738 lbs.

Weight at A.	Weight at B.	Weight at C.	Weight at D.	Deflection at B.	Deflection at C.	Deflection at D.	REMARKS.
lbs.	lbs.	lbs.	lbs.	ft. in.	ft. in.	ft. in.	
362	- - -	- - -	- - -	- - -	– 5	—	
362	30	15	30	2 2	2 11 $\frac{3}{4}$	2 1 $\frac{1}{4}$	
362	35	30	35	2 8	3 10 $\frac{3}{8}$	2 7 $\frac{1}{4}$	
362	40	35	40	2 11 $\frac{4}{10}$	4 3 $\frac{1}{2}$	2 10 $\frac{1}{2}$	
362	40	41	40	3 3	4 11	3 2 $\frac{1}{4}$	
468	56	41	56	3 4 $\frac{6}{10}$	4 9 $\frac{4}{10}$	3 4 $\frac{7}{10}$	
498	56	41	56	3 – $\frac{4}{10}$	4 3 $\frac{6}{10}$	3 – $\frac{6}{10}$	
558	61	41	61	3 1 $\frac{1}{2}$	4 4 $\frac{1}{4}$	3 1 $\frac{1}{4}$	
608	76	76	76	3 5 $\frac{9}{10}$	5 3 $\frac{3}{10}$	3 6 $\frac{1}{2}$	Fixed the wire at A.
Fixed -	56	56	56	3 –	4 6 $\frac{7}{10}$	2 11 $\frac{1}{2}$	
Ditto -	71	68	71	3 3 $\frac{8}{10}$	5 –	3 4	Refixed the wire.
Ditto -	ditto -	ditto -	ditto -	3 4 $\frac{7}{10}$	5 1 $\frac{3}{10}$	3 4 $\frac{7}{10}$	
Ditto -	77	74	77	3 6 $\frac{2}{10}$	5 4 $\frac{8}{10}$	3 6 $\frac{8}{10}$	Refixed the wire.
Ditto -	77	74	77	3 3 $\frac{7}{10}$	4 11 $\frac{8}{10}$	3 3 $\frac{2}{10}$	

Bore this weight; but in attempting to add four pounds more to the weights at B and D, the Wire broke.

Experiment, No. 4.

The same Wire as in last Experiment. Distance of the Props, 31 feet 6 inches.

Weight at A.	Weight at B.	Weight at C.	Weight at D.	Deflection at B.	Deflection at C.	Deflection at D.	REMARKS.
	lbs.	lbs.	lbs.	ft. in.	ft. in.	ft. in.	
Fixed -	- - -	- - -	- - -	- - -	– – $\frac{1}{8}$	- - -	Both ends fixed.
Ditto -	40	41	40	– 7 $\frac{5}{8}$	– 10 $\frac{7}{8}$	– 7 $\frac{1}{2}$	
Ditto -	44	47	44	– 8 $\frac{1}{2}$	1 – $\frac{1}{8}$	– 8 $\frac{1}{2}$	
Ditto -	50	47	50	– 9	1 – $\frac{5}{8}$	– 9	
Ditto -	56	47	56	– 9 $\frac{3}{4}$	1 1 $\frac{1}{4}$	– 9 $\frac{1}{2}$	
Ditto -	56	53	56	– 10 $\frac{1}{8}$	1 2	– 9 $\frac{3}{4}$	
Ditto -	61	53	61	– 10 $\frac{1}{2}$	1 2 $\frac{3}{8}$	– 10 $\frac{1}{4}$	
Ditto -	61	59	61	– 10 $\frac{3}{4}$	1 3 $\frac{1}{8}$	– 10 $\frac{3}{4}$	
Ditto -	67	68	67	1 –	1 4 $\frac{5}{8}$	– 11 $\frac{5}{8}$	
Ditto -	71	68	71	1 –	1 4 $\frac{7}{8}$	1 –	
Ditto -	71	76	71	1 – $\frac{1}{2}$	1 5 $\frac{1}{8}$	1 – $\frac{1}{4}$	

With the last Weights suspended a few minutes, the Wire broke.

Experiment, No. 5.

Distance of the Props, 100 feet; Diameter, $\frac{8}{100}$ of an inch; Weight of 100 feet, $16\frac{1}{3}$ ounces. Vertically, the Wire bore 277 lbs. a few minutes, and then broke.

Weight at A.	Weight at B.	Weight at C.	Weight at D.	Deflection at B.		Deflection at C.		Deflection at D.		REMARKS.
lbs.	lbs.	lbs.	lbs.	ft.	in.	ft.	in.	ft.	in.	
180	- - -	- - -	- - -	–	$1\frac{3}{4}$	–	$1\frac{1}{4}$	–	$1\frac{3}{4}$	
180	6	5	6	1	$-\frac{7}{8}$	1	$5\frac{1}{2}$	–	$11\frac{3}{4}$	
180	12	10	12	1	$10\frac{1}{8}$	2	$7\frac{3}{4}$	1	$9\frac{1}{2}$	
210	16	14	16	2	$3\frac{1}{2}$	3	$2\frac{1}{2}$	2	2	
248	16	14	16	2	$2\frac{5}{8}$	3	$2\frac{1}{2}$	2	$2\frac{1}{4}$	Took off the Weight A, and tightened the Wire.
Fixed -	16	14	16	1	$9\frac{5}{8}$	2	$7\frac{1}{4}$	1	$9\frac{1}{4}$	Broke the Wire, in attempting to draw it tighter.
Another piece of the same Wire.										
Fixed -	- - -	- - -	- - -	–	$2\frac{3}{4}$	–	4	–	$3\frac{1}{4}$	
Ditto -	16	15	16	2	4	3	5	2	$4\frac{7}{8}$	
Ditto -	22	19	22	2	$7\frac{1}{2}$	3	10	2	$8\frac{1}{10}$	

In attempting to increase these Weights to 25, 26 and 25 lbs., the Wire broke at a defective place.

Experiment, No. 6.

Same Wire as in the preceding Experiment. Distance of the Props, 31 feet 6 inches.

Weight at A.	Weight at B.	Weight at C.	Weight at D.	Deflection at B.		Deflection at C.		Deflection at D.		REMARKS.
	lbs.	lbs.	lbs.	ft.	in.	ft.	in.	ft.	in.	
Fixed -	22	30	22	–	$11\frac{1}{2}$	1	6	–	$10\frac{7}{8}$	
Ditto -	28	30	28	1	$1\frac{1}{4}$	1	$6\frac{1}{2}$	1	$-\frac{5}{8}$	
Ditto -	30	30	30	1	$1\frac{5}{8}$	1	$6\frac{1}{2}$	1	$1\frac{1}{8}$	
Ditto -	30	35	30	1	$1\frac{1}{2}$	1	$7\frac{5}{8}$	1	$1\frac{1}{8}$	

Broke, in attempting to add 4 lbs. more at B and D.

Experiment, No. 7.

Distance of the Props, 140 feet; Diameter, $\frac{1}{21}$ of an inch; Weight of 140 feet, 14 ounces.
Broke, vertically, with 157 lbs.

Weight at A.	Weight at B.	Weight at C.	Weight at D.	Deflection at B.		Deflection at C.		Deflection at D.		REMARKS.
lbs.	lbs.	lbs.	lbs.	ft.	in.	ft.	in.	ft.	in.	
120	- - -	- - -	- - -	–	1 $\frac{1}{2}$	–	1 $\frac{5}{8}$	–	1 $\frac{3}{8}$	
120	6	5	6	2	8	3	5 $\frac{2}{10}$	2	7 $\frac{3}{4}$	
120	12	10	12	4	8 $\frac{3}{10}$	6	4 $\frac{1}{2}$	4	7 $\frac{1}{10}$	
120	15	20	15	7	1 $\frac{1}{2}$	10	–	7	– $\frac{3}{4}$	
132	15	20	15	6	3 $\frac{1}{4}$	8	9 $\frac{1}{2}$	6	4 $\frac{1}{2}$	
132	21	25	21	8	8 $\frac{1}{2}$	11	11	8	7	
150	21	25	21	7	11 $\frac{1}{2}$	10	10	7	–	
150	25	25	25	8	3	10	11	8	2	Broke.

Experiment, No. 8.

Same Wire as in the last Experiment. Distance of the Props, 31 feet 6 inches.

Weight at A.	Weight at B.	Weight at C.	Weight at D.	Deflection at B.		Deflection at C.		Deflection at D.		REMARKS.
	lbs.	lbs.	lbs.	ft.	in.	ft.	in.	ft.	in.	
Fixed -	- - -	- - -	- - -	–	5 $\frac{1}{2}$	–	5 $\frac{1}{4}$	–	4 $\frac{1}{2}$	
Ditto -	6	5	6	1	1 $\frac{3}{4}$	1	4 $\frac{1}{4}$	1	1 $\frac{1}{2}$	
Ditto -	12	10	12	1	4 $\frac{3}{4}$	1	8	1	3 $\frac{1}{4}$	
Ditto -	16	15	16	1	6 $\frac{1}{4}$	1	10 $\frac{1}{2}$	1	4 $\frac{7}{8}$	
Ditto -	20	20	20	1	7 $\frac{1}{2}$	2	1	1	6 $\frac{3}{8}$	

Broke, in attempting to add 2 lbs. at B, 4 lbs. at C, and 2 lbs. at D.

Experiment, No. 9.

The same Wire as last Experiment, and the Props the same distance; viz. 31 feet 6 inches.

Weight at A.	Weight at B.	Weight at C.	Weight at D.	Deflection at B.	Deflection at C.	Deflection at D.	REMARKS.
lbs.	lbs.	lbs.	lbs.	ft. in.	ft. in.	ft. in.	
120	20	30	20	2 6	3 3 $\frac{1}{2}$	2 2 $\frac{1}{4}$	
120	25	30	20	2 9 $\frac{1}{4}$	3 7	2 5	
120	31	34	31	3 5 $\frac{4}{10}$	4 4 $\frac{1}{2}$	2 11 $\frac{1}{2}$	
120	34	34	34	3 6 $\frac{2}{4}$	4 5 $\frac{1}{2}$	3 1 $\frac{1}{4}$	
120	34	42	34	3 9 $\frac{3}{4}$	4 11 $\frac{1}{4}$	3 2 $\frac{2}{4}$	
120	34	50	34	4 –	5 3 $\frac{1}{4}$	3 4	
150	34	50	34	3 3 $\frac{6}{10}$	4 4 $\frac{1}{2}$	2 9 $\frac{8}{10}$	
150	34	55	34	3 6 $\frac{1}{4}$	4 8 $\frac{1}{2}$	3 –	
150	37	55	37	3 9 $\frac{4}{10}$	5 –	3 2 $\frac{1}{2}$	
150	37	56	37	3 9 $\frac{1}{4}$	5 –	3 2 $\frac{1}{2}$	
156	37	56	37	3 9 $\frac{1}{4}$	5 –	3 2 $\frac{1}{2}$	
160	39	57	39	3 9 $\frac{2}{10}$	5 – $\frac{3}{10}$	3 2 $\frac{2}{10}$	Broke, in attempting to add 6 lbs. more.

Note :—The above experiments were made at the patent iron cable manufactory of Messrs. Brunton & Co.

Experiment, No. 10.

Distance of the Props, 900 feet; Diameter of Wire, one-tenth of an inch; Wei[illegible] eet. 28 lbs. by the steel-yard; Weight of 100 feet, 3 lbs. 3$\frac{1}{2}$ oz. by the scal[illegible]; [illegible] ical strength, from nine experiments, 630 lbs.

Weight at A.	Weight at B.	Weight at C.	Weight at D.	Distance of C. from the ground.	REMAI[illegible]
	lbs.	lbs.	lbs.	ft. in.	
Fixed -	- - -	- - -	- - -	15 6	On account of the length of the wire, the curvature was measured from the ground; which latter was ab[illegible] 22 fe[illegible] from the hori[illegible]ntal [illegible]ine, between the pr[illegible] or points of [illegible]uspension.
Ditto -	28	14	28	4 – $\frac{1}{2}$	
Ditto -	28	17	28	3 4	
Ditto -	28	19	28	3 –	
Ditto -	28	20	28	2 10	
Ditto -	28	21	28	2 5 $\frac{1}{2}$	
Ditto -	28	22	28	2 4	Removed th[illegible] weights, and tighten[illegible] the wire.
Ditto -	- - -	- - -	- - -	16 8	
Ditto -	28	- - -	28	9 1	
Ditto -	28	14	28	4 8	
Ditto -	28	17	28	- - - -	Broke the wire; not at a joint.

This experiment was made at Ellesmere; the points of suspension were, at one end a building, at the other a tree.

The nine experiments from which the mean vertical strength of six hundred and thirty pounds was deduced are as follow:

	lbs.
1st broke with - - - - - - - - - -	616
2d - - - - - - - - - - -	616
3d - - - - - - - - - - -	620
4th - - - - - - - - - - -	652
5th - - - - - - - - - - -	616
6th - - - - - - - - - - -	637
7th - - - - - - - - - - -	616
8th - - - - - - - - - - -	646
9th - - - - - - - - - - -	651
	9)5,670
Mean of Nine Experiments -	630 lbs.

The wire broke in these experiments at joints or unsound places.

The mean of twelve other experiments on wires of the same diameter, but of different specimens, was six hundred and thirty-four pounds.

Experiments

On the Momentum which Wires stretched, as in the preceding Experiments, will bear before breaking.

Experiment 1.—A piece of wire which bore vertically two hundred and seventy-seven pounds, was stretched between two props, one hundred and forty feet distant from each other, till the versed sine or deflection in the centre was only four and three quarter inches.

A five pound weight was then tied to a cord, and the other end fastened to the middle of the wire; the length of the cord between the weight and the wire was ten feet six inches. The weight being now lifted up to the level of the wire, it was let fall, and struck the ground, but without injuring the wire.

Shortened the cord to seven feet seven inches, and proceeded as above: it did not strike the ground, nor did it injure the wire.

With the same length of cord and a ten pound weight instead of the five pound, proceeded in the same manner; struck the ground, but did not break the wire.

But the same weight hung by a string six feet seven inches, let fall as above, broke the wire at a joint.

Note:—The distance of the middle of the wire from the ground was thirteen feet six inches.

By the law of falling bodies, we have for the

1st momentum - - - $(8 \times \sqrt{10{\cdot}5} = 3{\cdot}225 \times 5 = 129$

2d - - - - - $(8 \times \sqrt{7{\cdot}58} = 2{\cdot}75 \times 5 = 110$

3d - - - - - $(8 \times \sqrt{7{\cdot}58} = 2{\cdot}75 \times 10 = 220$

4th - - - - - $(8 \times \sqrt{6{\cdot}58} = 2{\cdot}55 \times 10 = 204$

As the last momentum is less than the preceding, we may infer that the wire was damaged in the third trial.

Experiment 2.—Distance of the props, thirty-one feet six inches; diameter of the wire one-tenth of an inch; stretched to within one-eighth of an inch of a strait line.

A ten pound weight was tied to the middle of the wire by a cord seven feet nine inches long: it was lifted up to the level of the wire as in the last experiment, and then let fall; but it did n–' [illegible]e wire.

A fifteen pound weight was tied and let fall in the same manner, without breaking the wire.

A twenty pound weight was then tried: it did not break the wire.

A twenty-five pound weight being let fall from the same height, broke the wire.

Here our four momenta are,

1st momentum - -	(8 × $\surd$ 7·75 = 2·7825 × 10 = 222·6	
2d - - - - -	(1 × $\surd$ 7·75 = 22·26 × 15 = 333·9	
3d - - - - -	(8 × $\surd$ 7·75 = 2·7825 × 20 = 445·2	
4th - - - - -	(8 × $\surd$ 7·75 = 2·7825 × 25 = 556·5	

Comparing these momenta with the direct vertical strength, we have—

1st vertical strength - - - - - 277 lbs. momentum 220;

2d ditto for wire of $\frac{1}{10}$ inch - - 630 lbs. ditto 556·5;

that is, in the first experiment, the number expressing the momentum is less by one-fifth than the vertical strength; and in the second by one-eighth; but it is probable that in the latter the wire would have been broken with a less weight than twenty-five pounds.

Experiments

Upon the direct Strength of Cohesion of malleable Iron, made at Messrs. Brunton and Company's Patent Chain Cable Manufactory, with an Hydrostatic Machine or Bramah Press, constructed by Mr. Fuller. By *Thomas Telford*, Esq.

Experiment, No. 1.—Cylindrical bar of South Wales iron, manufactured by S. Homfrey, Esq.

April 5th, 1814.	Length of bar when put in -	2 feet $2\frac{3}{4}$ inches.
	Ditto when taken out - -	2 „ $6\frac{7}{8}$ „
	Diameter when put in - - -	– „ $1\frac{3}{8}$ „
	Ditto when taken out - - -	– „ $1\frac{1}{8}$ „

Torn asunder by 43 tons, 11 cwt.

Experiment, No. 2.—Cylindrical bar of South Wales iron, manufactured by S. Homfrey, Esq.

April 5th, 1814.	Length of bar when put in -	2 feet $3\frac{3}{8}$ inches.
	Ditto when taken out - -	2 „ $6\frac{5}{8}$ „
	Diameter when put in - - -	– „ $1\frac{1}{2}$ „
	Ditto when taken out - - -	– „ $1\frac{1}{4}$ „

Torn asunder by 52 tons, 15 cwt. 1 qr. 10 lbs. Time thirty-four minutes.

Experiment, No. 3.—Square bar of Staffordshire iron.

May 17th, 1814 -	Length of bar when put in	- -	1 foot $5\frac{1}{8}$ inches.
	Ditto when taken out	- -	1 „ $11\frac{1}{4}$ „
	Side of square when put in	- -	– „ – $\frac{3}{4}$ „
	Ditto when taken out	- -	– „ – $\frac{6}{10}$ „

Began to stretch with 12 tons; broke with 15 tons, 5 cwt. 3 qrs. 4 lbs. Time, $9\frac{1}{4}$ minutes.

Experiment, No. 4.—Square bar of Staffordshire iron.

May 17th, 1817 -	Length of bar when put in	- -	1 foot $7\frac{1}{4}$ inches.
	Ditto when taken out	- -	1 „ $9\frac{1}{4}$ „
	Side of square when put in	- -	– „ $1\frac{1}{12}$ „
	Ditto when taken out	- -	– „ – $\frac{5}{6}$ „

Began stretching with 32 tons; broke with 32 tons, 6 cwt. 4 lbs.
Time, 16 minutes.

Experiment, No. 5.—Square bar of Welsh iron, one inch square.

May 5th, 1817 - -	With 18 tons stretched	- -	– $\frac{1}{4}$ inches.
	With 21 „ ditto	- - -	– $\frac{1}{2}$ „
	With 23 „ ditto	- - -	– $\frac{3}{4}$ „
	With 25 „ ditto	- - -	1 „
	With 27 „ ditto	- - -	$2\frac{1}{4}$ „
	With 29 „ ditto	- - -	$2\frac{3}{8}$ „

Broke with this weight.

Experiment, No. 6.—Bar of Swedish iron, one inch square.

May 5th, 1817 - -	Began to stretch with 17 tons.		
	Stretched with	- -	20 tons,—one-tenth of an inch.
	Ditto „	- -	27 tons,—three-eighths ditto.
	Ditto „	- -	29 tons;—broke at a flaw.

Note:—The above and following stretchings were measured on twelve inches in the middle of the bar.

Experiment, No. 7.—Bar of faggoted iron, from scrap iron, by M. Howard, of Rotherhithe, one inch square.

May 5th, 1817 - -	Began to stretch with 16 tons.		
	Stretched with	-	20 tons,—three-eighths of an inch.
	Ditto „	-	25 tons,—three-quarters ditto.
	Ditto „	-	28 tons,—two and three-eighths ditto.
	Ditto „	-	29 tons;—broke with this weight.

Note:—A similar bar began to stretch with eighteen tons, and broke with the same weight; viz. twenty-nine tons.

Experiment, No. 8.—Bar of common Staffordshire iron, one inch square.

May 5th, 1817 - -	Began to stretch with 19 tons.		
	Stretched with	- -	24 tons,—half an inch.
	Ditto „	- -	28 tons,—five-eighths ditto.
	Ditto „	- -	29 tons,—five-eighths ditto.
	Ditto „	- -	30 tons,—one inch.
	Ditto „	- -	31 tons;—broke with this weight.

Experiment, No. 9.—Cylindrical bar of common iron, two inches diameter.

May 21st, 1817.	With 45 tons	Began to stretch about one-tenth of an inch on twelve inches in the middle. The machine being relieved, the bar shortened one-fortieth of an inch.
	With 50 „	Stretched ·125 inch; relieved and shortened, as before.
	With 55 „	- ditto - ·25 inch - - - ditto.
	With 60 „	- ditto - ·26 „
	With 70 „	- ditto - ·375 inch; recovered very little when the machine was relieved.
	With 75 „	- ditto - ·544 - - - ditto.
	With $80\frac{1}{10}$ „	- ditto - ·75; reduced in diameter to $1\frac{1}{16}$ inch.
	With 85 „	- ditto - ·86; no perceptible change.
	With 90 „	- ditto - 1·00 - - - ditto.
	With 95 „	- ditto - 1·35; reduced in diameter to $1\frac{7}{8}$ inch.
	With 100 „	- ditto - 2·2 - - - ditto - to $1\frac{1}{2}$ nearly.

With the last weight the bar gave evident signs of fracture, and, in a few minutes, gradually gave way.

Note :—The whole length of the above bar was two feet; and it stretched, in its whole length, two inches and seven-eighths; of which, two inches and one-fifth were in twelve inches in the middle part. The whole time of making this experiment was three hours, and it was performed with the utmost care.

The machine was frequently relieved; and when re-applied, constantly brought up the weight to what it was before, but never exceeded it; which is evidence of its accuracy.

Note :—It is a curious fact, and deserving the attention of philosophers, that frequently, at the moment of rupture, the bar acquires such a degree of heat in the fractured part, as scarcely to enable a person to hold it grasped in his hand without a painful sensation of burning.

Reduction of the above to one inch square.

	Tons.	Feet.
No. 1. (South Wales iron) reduced to one inch square - gives	29	6
No. 2. - - (ditto) - - - - - - - - - - -	29	16
No. 3. (Staffordshire iron) - - - - - - - - -	27	3
No. 4. - (ditto) - - - - - - - - - - -	27	10
No. 5. (Welsh iron) - - - - - - - - - -	29	–
No. 6. (Swedish iron) - - - - - - - - - -	29	–
No. 7. (faggoted iron) - - - - - - - - -	29	–
No. 8. (Staffordshire iron) - - - - - - - -	31	–
No. 9. (cylindrical bar of common iron) - - - - - -	31	16
	9)263	11
Mean strength of an inch square bar - -	29	5 $\frac{2}{3}$

Reducing the experiments reported at p. 561, on wire, to the same standard, we find the strength equal to $35\frac{9}{11}$ tons to the square inch.

According to Capt. Brown:

			Tons.
No. 1.	Swedish iron - - - - - -	1 square inch - - -	23·77
No. 2.	- ditto - - - - - - - -	ditto - - - -	23·19
No. 3.	- ditto - - - - - - - -	ditto - - - -	23·75
No. 4.	Russia - - - - - - - - -	ditto - - - -	26·55
No. 5.	Welsh - - - - - - - - -	ditto - - - -	24·35
No. 6.	ditto - - - - - - - - -	ditto - - - -	24·90
No. 7.	ditto - - - - - - - - -	ditto - - - -	26·33
No. 8.	Blistered steel - - - - - -	ditto - - - -	14·27
No. 9.	Cast steel - - - - - - - -	ditto - - -	27·92
No. 10.	Cast-iron, Welsh pig - - -	ditto - - - -	7·26
No. 11.	Welsh - - - - - - - - -	ditto - - - -	26·34

Mean of the first seven, and the eleventh experiments -	25 tons.
Mean of Mr. Telford's experiments - - - - -	29 $\frac{1}{4}$ tons.
And the mean of the two - - - - - - -	27 tons nearly.

By comparing the mean result of Mr. Telford's experiments with that deduced from the experiments by Capt. Brown, a considerable difference is thus found, which it is important to explain, and which appears to be attributable to the operation of the two machines; viz., the one over-rating its power, and the other falling short of it. Messrs. Brunton and Company's machine is an hydraulic press; in which, with high pressures, there is necessarily great friction between the piston leather and the barrel, and the power of the machine is opposed both to the resistance and friction: therefore, if we estimate the whole as opposed to resistance only, the strain will be over-rated. In Capt. Brown's machine the case is exactly reversed; the friction and inertia having both a tendency to make its apparent power too small.

APPENDIX (O. 5.)

DESIGN for a SUSPENDED CENTERING for constructing an IRON ARCH over the *Menai Strait* (at *Ynys-y-moch*).

THE other design is for the narrower strait called Ynys-y-moch. Here the situation is particularly favourable for constructing a bridge of one arch; and by making that arch five hundred feet span, I leave the navigation as free as at present. In this design I have made the height one hundred feet in the clear, at high-water spring tides, and I propose this bridge to be forty feet in breadth. Estimating the expense from drawings, (as already described), I find the expense to be £.127,331. From leaving the whole channel unimpeded, it is certainly the most perfect scheme of passing the Menai, and it would, in my opinion, be attended with the least inconvenience and risk in the execution.

In order to render this evident, I have made a drawing [*see* Plate 77], to show in what manner the centering or frame for an arch of this magnitude may be constructed. Hitherto the centering has been made by placing supports, and working from below; but, in the case of the Menai, from the nature of the bottom of the channel, the depth at low-water, and the great rise and rapidity of the tides, this would be very difficult, if not impracticable. I therefore propose changing the mode, and working entirely from above; that is to say, instead of supporting, I mean to suspend the centering. By inspecting the drawing, the general principle of this will be readily conceived.

I propose, in the first place, to build the masonry of the abutments as far back as the lines A B, C D, and in the particular manner shown in the section.

Having carried up the masonry to the level of the roadway, I propose, upon the top of each abutment, to construct as many frames as there are to be ribs in the centres, and of at least an equal breadth with the top of each rib. These frames to be about fifty feet high above the top of the masonry, and to be rendered perfectly firm and secure. That this can be done is so evident, I avoid entering into details respecting the mode. These frames are for the purpose of receiving strong blocks, or rollers and chains, and to be acted upon by windlasses or other powers.

I next proceed to construct the centering itself; it is proposed to be made of deal baulk, and to consist of four separate ribs, each rib consisting of a continuation of timber frames, five feet in width across the top and bottom, and varying in depth from twenty-five feet near the abutment, to seven feet six inches at the middle or crown. Next to the face of the abutment, one set of frames about fifty feet in length can, by means of temporary scaffolding and iron chain bars, be readily constructed and fixed upon the masonry offsets of the abutment, and to horizontal iron ties laid into the masonry for this purpose. A set of these frames (four in number) having been fixed against the face of each abutment, they are to be secured together by cross and diagonal braces; and there being spaces of only six feet eight inches left between the ribs (of which these frames are the

commencement) they are to be covered with planking, and the whole converted into a platform fifty feet by forty. By the nature of the framing, and from its being secured by horizontal and suspending bars, I presume every person accustomed to practical operations will admit that these platforms may be rendered perfectly firm and secure.

The second portion of the centering frames having been previously prepared and fitted together in the carpenter's yard, are brought in separate pieces, through passages purposely left open in the masonry to the before-mentioned platform; they are here put together, and each frame raised by the suspending chain bars and other means, so that the end which is to be joined to the frame already fixed shall rest upon a small movable carriage; it is then to be pushed forward, perhaps upon an iron railroad, until the strong iron forks which are fixed upon its edge shall fall upon a round iron bar which forms the outer edge of the first or abutment frames; when this has been done, strong iron bolts are put through eyes in the forks, and the aforesaid second portion of frame-work is suffered to descend to its intended position by means of the suspending chain bars, until it closes with the end of the previously fixed frame like a rule joint. Admitting the first frames were firmly fixed, and that the hinge part of this joint is sufficiently strong, and the joint itself about twenty feet deep, I conceive that even without the aid of the suspending bars, this second portion of the centering would be supported; but we will for a moment suppose that it is to be wholly suspended. It is known by experiments, that a bar of good malleable iron, one inch square, will suspend eighty thousand pounds, and that the powers of suspension are as the sections; consequently, a bar of an inch and a half square will suspend one hundred and eighty thousand pounds. But the whole weight of this portion of rib, including the weight of the suspending bar, is only about thirty thousand pounds, or one-sixth of the weight that might be safely suspended; and as I propose two suspending chain-bars to each portion of rib, if they had the whole to support they would only be exerting about one-twelfth of their power; and considering the proportion of the weight which rests upon the abutments, they are equal also to support all the iron-work of the bridge, and be still far within their power.

Having thus provided for the second portions of the centering a degree of security far beyond what can be required, similar operations are carried on from each abutment, until the parts are joined in the middle, and form a complete centering; and being then braced together, and covered with planking where necessary, they become one general platform or wooden bridge on which to lay the iron-work.

It is, I presume, needless to observe, that upon such a centering or platform the iron-work, which it is understood has been previously fitted, can be put together with the utmost correctness and facility. The communications from the shores to the centering will be through the before-mentioned passages left in the masonry.

The form of the iron-work of the main ribs will be seen by the drawings to compose a system of triangles, preserving the principal points of bearing in the direction of the radius. It is proposed in the breadth of the bridge (i. e. forty feet) to have nine ribs, each cast in twenty-three pieces, and these connected by a cross-grated plate, nearly in the same manner as in the great aqueduct of Pontcysylte, over the valley of the Dee, near Llangollen. The fixation of the several ribs in a vertical plane appearing (after the abutments) to be the most

important object in iron bridges, I propose to accomplish this by covering the several parts, as they are progressively fixed, with grated or reticulated and flanched plates across the top of the ribs. This would keep the tops of the ribs immovable, and convert the whole breadth of the bridge into one frame. Besides thus securing the top, I propose also having cross braces near the bottom of the ribs.

The main ribs being thus fixed, covered and connected together, the great feature of the bridge is completed; and as, from accurate experiments made and communicated to me by my friend the late William Reynolds, of Coalbrook Dale, it requires four hundred and forty-eight thousand pounds to crush a cube of one quarter inch of cast iron of the quality called gun-metal, it is clear, that while the ribs are kept in their true position, the strength provided is more than ample.

When advanced thus far, I propose (though not to remove, yet) to ease the timber centering,—the feet of the centering ribs (which are supported by off-sets in the masonry of the front of the abutment) having been for that purpose placed upon proper wedges; the rest of the centering to be eased at the same time by means of the chain bars. Thus, the hitherto dangerous operation of striking the centering will be rendered gradual and perfectly safe; insomuch, that this new mode of *suspending* the centering instead of *supporting* it from below, may perhaps hereafter be adopted as an improvement in constructing iron bridges, even in places not circumstanced as are the Menai Straits. Although the span of the arch is unusually great, yet by using iron as a material, the weight upon the centering, when compared with large stone arches, is very small; taking the mere arch stones of the centre arch of Blackfriars bridge at 156 × 43 × 5 equal to thirty-three thousand five hundred and forty cubic feet of stone, it amounts to two thousand two hundred and thirty-six tons; whereas the whole of the iron-work in the main ribs, cross-plates and ties, and grated covering-plates, that is to say, all that is lying on the centering at the time it is to be eased, weighs only one thousand seven hundred and ninety-one tons. It is true, that from the flatness of the iron arch, if left unguarded, a great proportion of this weight would rest upon the centering; but this is counterbalanced by the operation of the iron ties in the abutments, and wholly commanded by the suspending chain bars.

When the main iron ribs have been completed, the next step is to proceed with the iron supporters of the roadway, and these, instead of being constructed in the form of circles, or that of perpendicular pillars, as hitherto, are here a series of triangles, thus including the true line of bearing. These triangles are, of course, preserved in a vertical plane by cross-ties and braces; iron bearers are supported by these triangles, and upon the bearers are laid the covering plates under the roadway, which, instead of being solid, are (in order to lessen the weight) proposed to be reticulated.

If I have, throughout this very succinct description, made myself understood, it will, I think, be admitted, that the constructing a single arch across the Menai is not only a very practicable, but a very simple operation; and that it is rendered so, chiefly, by adopting the mode of working from each abutment, without at all interfering with the tideway.

Thomas Telford.

22 April 1811.

APPENDIX (O. 6.)

PARTICULARS of the GRAND SUSPENSION BRIDGE erected over the Straits of *Menai*, designed by *Thomas Telford*, Civil Engineer.—Begun in May 1819, and opened January 30th, 1826.—Narrated by Dr. *Pring*. *Bangor*, 1828.

PREFACE.

IT may possibly happen that a person, in perusing the title of this pamphlet, will erroneously conclude, without noticing its diminutive size, that it contains a specification, with descriptive plans, sections, elevations, &c., of the magnificent bridge alluded to, displayed as a guide to the aspirant. In this respect he will, however, find himself egregiously mistaken. He might just as well expect, by the aid of this simple narrative, to 'build castles in the air;'

> 'Snap oaks, like twigs, across the knee,
> 'Quench Etna with a cup of tea;
> 'Sound, with a needlefull of thread,
> 'The depth of ocean's briny bed.'

The 'Particulars' hereafter described are, in fact, neither more nor less than a recapitulation of the PROGRESS of the work, as it appeared to an admiring observer from its first commencement—the nature and quality of the stone, the mode of taking over the suspension chains, &c.—to its completion; interspersed with a few incidental occurrences.

The humble Author of this epitome (wholly devoid of architectural talent) resided about a mile from the spot where the Menai Bridge is erected. Innate curiosity drew him frequently to the spot, to observe the growing 'form and feature' of a structure so novel, and which has left an indelible reminiscence on 'the mind's eye.'

He waited anxiously expecting an abler pen would undertake the task; he was disappointed, and now comes forward as the timorous narrator, to record an Era which will be considered by future ages as a prominent feature in the annals of Wales.

It must be universally allowed, that no one can give the world any adequate idea of the design, construction and execution of the Menai Suspension Bridge in all its varied and complicated parts, except the renowned projector himself.

Should such a publication emanate from the erudite pen and luminous mind of Mr. Telford, this puerile attempt must necessarily 'hide its diminished head,' and sink into the shade of oblivion.

Mem.—*Mr. Telford thought much more highly of this Narrative than did its modest Author; and destined for it a place in his Appendix, as detailing interesting anecdotes, which could not so well be introduced in any official statement.*—EDITOR.

LINES addressed to Mr. *Telford*, on viewing the MENAI SUSPENSION BRIDGE, and the GRAND AQUEDUCT over the river *Dee*, as existing and incontrovertible evidence of his pre-eminent Genius.

THE following elegant lines, from the pen of the celebrated Robert Southey, Esq., Poet Laureat, are inscribed to Thomas Telford, Esq., in allusion to his superior talents exemplified in the construction and erection of the superb aqueduct over the river Dee, called Pont Cyssylltir,* and the grand Menai suspension bridge—both in North Wales.

TELFORD—who o'er the vale of Cambrian Dee,
Aloft in air, at giddy height upborne,
Carried his navigable road, and hung
High o'er Menai's Straits, the bending bridge;
Structures of more ambitious enterprise
Than minstrels, in the age of old romance,
To their own Merlin's magic lore ascribed.

ANCIENT WELSH PREDICTION, adverting to the erection of a Bridge over the Straits of *Menai*.

THE following traditionary couplet, which has never before appeared in print (though successively communicated, orally, from father to son) is currently said, and generally believed, by many persons now living, to have been uttered by the celebrated seer, Robin Ddû, who lived about the close of the sixteenth century, and was remarkable for his 'dark sayings.' He resided in a small cottage, called Yr Aelwyd isa' yn Nghymru—'the lowest hearth in Wales'—situate on the western boundary of the parish of Bangor, contiguous to the straits of Menai; the foundation of the building is still visible. The distich is as follows:—

'Dwy flynedd, cyn aflonydd,
'Pont ar Fenai fydd.'

Which, translated literally, runs thus:—'Two years before tumult, there will be a bridge over the Menai.'

The drift of this prediction seems, at present, inexplicable; but time, that brings to light 'the hidden things of this world,' will ere long unfold 'the mystery profound.'

There are several other ominous predictions by Robin Ddû, still extant, of 'local 'forebodings,' which are omitted here, as irrelevant to the present subject.

PARTICULARS of the MENAI SUSPENSION BRIDGE.

First Commencement of the MENAI SUSPENSION BRIDGE, on *Ynys-y-moch*, a natural rock, situate about Forty Yards from the *Anglesey*, or West Shore of the *Menai Strait*, near *Bangor Ferry*.

THE first process towards the erection of this truly magnificent and unrivalled bridge took place in the month of May 1819, by blasting and removing the inequalities of the rock called Ynys-y-moch (which, at that time, was accessible only at low-water) to an

* From the British of *pont*, a bridge; *cyssylltu*, to unite; *tir*, land.

even surface, in order to form thereon a solid foundation for the west main pier on the Anglesey side. For this purpose, in a few months afterwards, the intermediate space between the Anglesey shore and the rock was filled up with a temporary causeway of stone-work, wide enough on the summit to admit of a railroad for sledges drawn by horses, and which, being considerably elevated above high-water mark, afforded the workmen an opportunity of passing and repassing to their various occupations, at all times, without hindrance.

The tide being thus shut out from its usual passage through this narrow strait, of course increased the velocity of the current in the centre of the channel, which was afterwards strikingly evident to those crossing in the ferry-boats during the ingress of the tide.

Previous, however, to the shutting up of the navigation (as authorized by an Act of Parliament), for the purpose of carrying the suspension chains over without interruption by vessels passing through the straits, this temporary causeway was taken down, and the channel made considerably deeper and wider than before, by which means coasting vessels, of a moderate tonnage, were now for the first time enabled to pass through this narrow strait with perfect ease, safety and facility, which before was impracticable, the passage being then impeded by a sort of embankment, raised about six feet above low-water mark, and formed of loose stones, over which horned cattle were drove, preparatory to swimming them across the main channel of the river, from Ynys-y-moch to the Carnarvonshire side, when the tide was weak and at its lowest ebb.

Many valuable head of cattle have, at different times, been drowned, in attempting to swim across this dangerous passage, by being carried away, and irrevocably lost, by the irresistible impulse of the stream.

The impetus of the tide in this part of the strait is at the rate of five miles per hour, independent of the influence of wind, which adds materially to its natural rapidity.

Laying the first Stone of this Stupendous Structure.

The temporary causeway (before alluded to) being completed, and the superficies of the rock (Ynys-y-moch) rendered even by the aid of masonry, the first stone of this wonderful work was laid (without the least appearance of pageantry, and, it may be added, with the utmost privacy) by Mr. W. A. Provis, the resident engineer, on Tuesday, the 10th day of August 1819, at ten o'clock in the forenoon.

Late in the autumn of the same year, the preparation for the foundation of the south main pier, on the Carnarvonshire side, was begun. After excavating the beach to the depth of seven feet, a solid mass of firm rock was fortuitously met with, on which the present east main pier rests its 'ponderous weight.'

This pier, from the extreme depth of its foundation, exceeds considerably, in quantum of masonry and workmanship, its gigantic rival on the opposite shore, the latter resting its base on Ynys-y-moch, the summit of which, in its natural state, is about six feet above high-water mark. This distinction is very evident at low-water.

The most eligible view of the bridge, in its present finished state, is from the sea-shore, just below the Laundry-house, belonging to Gorphwysfa, a short distance south-west of Bangor Ferry Inn.

Of the Seven Arches which support the Roadway, leading to and from the Bridge.

The four arches on the Anglesey side, and the three on the Carnarvonshire side, which exceed in magnitude and grandeur every work of the kind in Europe, were begun early in the spring of 1820, and completed late in the autumn of 1824.

[Precise dimensions of these arches will be given at the end of this narrative.]

Quality of the Stone.

The beautiful grey marble, which takes a fine polish, of which the entire masonry of this superb work is built, was procured on the sea-shore, at Penmon, on the north-east extremity of the island of Anglesey, about seven miles from Beaumaris, on the property of Lord Viscount Warren Bulkeley; for which his Lordship was paid by Government sixpence per ton.

The stone, which in its natural state is formed in layers or shelves, and capable of being cut in solid blocks of any given length or dimensions (without the aid of powder), was conveyed from the quarries, along the sea-coast, passing through the picturesque bay of Beaumaris, to Bangor ferry, a distance of about twelve miles, by small coasting vessels employed for that particular purpose; three of which were, during tempestuous weather, unfortunately wrecked near Puffin Island, while endeavouring to pass through the Sound, where several vessels from distant parts have met with a similar fate.

During the erection of the bridge, many of the more industrious workmen employed their leisure hours by polishing waste pieces of this beautiful and frequently variegated marble, and forming them into letter-pressers, ink-stands and chimney-ornaments, neatly executed, which have been eagerly purchased by those who came to visit this grand specimen of British architecture.

Of the two Main Piers.

It is proper to observe, that the abutments of the two main piers are not formed of a solid bed of stone-work all the way up; on the contrary, eight hollow squares (four in each pier) were left near the centre of the abutments, commencing above high-water mark, and continued up, perpendicularly, nearly to the level of the roadway, which, as the pier advanced in altitude, were regularly worked within, and closely cemented with mortar, in the same manner as the external face of the pier. This method of forming wide abutments adds greatly to the strength and solidity of the interior of the work by binding the masonry more closely together,—a self-evident position.

Of the Suspension Piers, being a continuation of the Main Piers.

After the completion of the seven arches (being mentioned above), the small arches intended for the roadways were constructed, each being fifteen feet to the spring of the arch, and nine feet in width, through which carriages, &c., are to pass.

After the arches were turned, the suspension piers were further elevated, tapering gradually, in a pyramidical form, to the height of fifty-three feet from the level of the road, by solid masonry; each stone, from the bottom to the top of the suspension piers being bound together with iron dowels, to prevent the possibility of being separated or bulged by the immense pressure and weight of the suspension chains.

The stone-work being thus far completed, the next process was in the

Iron Department.

On the extreme height of the suspension piers are placed the cast-iron blocks or saddles (with wrought-iron rollers, and brass bushes), for the purpose of regulating the contraction and expansion of the iron, by moving themselves either way, as may be required, according to the temperature of the atmosphere, without causing the least derangement in any part of the work. These self-acting rollers are most ingeniously constructed, and form a desideratum in this line of bridge-building.

Of the Iron Frames, to which the Suspension Chains are fastened.

In order to form a permanent seat, grasp or hold for the iron frames, to which the lower or extreme ends of the suspension chains were to be made fast, three oblique cavities or openings were made, of a circular form, about six feet diameter, by blasting in a natural body of rock on the Anglesey side, leaving a considerable width of rock between each opening, which afterwards served as a passage for the suspension chains. These excavations were carried down like an inclined plane to the depth of twenty yards.

This being accomplished, a connecting avenue, chamber or cavern was formed horizontally at the bottom of the cavities, sufficiently capacious for the workmen to fix the iron frames (composed principally of flat cast-iron plates), which were afterwards ingrafted (as it were) by initiation in the natural rock, so as to bid defiance to any stress that might bear upon them, and immovable, until the whole mass of solid rock itself gives way. This cavern can now be entered from a passage, bored purposely through the same rock below the level of the roadway, on the south-west side of the bridge.

A similar mode of proceeding was adopted on the Carnarvonshire side, but as the rock was situated at a greater distance from the bed of the river than that on the Anglesey side, and having also to cut through a considerable bank of earth, it turned out an undertaking of immense labour, and took up a considerable time to accomplish it. This accounts for the disproportion apparent in the catenary or chord line of the suspension chains, when viewed from the toll-houses.

The iron frames being thus permanently fixed and adjusted, the next operation was

Fixing the Suspension Chains, made exclusively of Wrought Iron.

The suspension chains being firmly secured, and made fast to the iron frames (before treated of), the chain bars, each ten feet in length, were then laid down by placing five together (equivalent to one breadth of chain), and carried on, by consecutive lengths joined by flat iron plates and bolts, to the apex of the suspension piers, supported underneath all the way up by a frame-work of strong timber; the upper end of the chain

resting on the cast-iron saddles, which had been placed there to receive them.—(*Vide* page 573.)

The reader will bear in mind, that at this period the suspension chains were carried no further from the fastenings in the rock on each side than the top of the suspension piers, leaving the chain disjunct, with an open space intervening between the two suspension piers, for the curved part of the chain, which in reality is the actual line of suspension, on which hangs the whole weight of the roadway, or any additional weight added thereto by loaded waggons, heavy droves of cattle, or any other excessive weight passing over it.

It now becomes necessary to explain how the open space between the two opposite ends of the chain was filled up, and the (at present disjunct) ends of the chains were made continuous to each other, so as to form a complete chain.

But first, it must be premised, that the part of the chain on the Carnarvonshire side was afterwards lengthened, by adding additional chain-bars from the apex of the suspending pier until it reached down, perpendicularly, nearly to high-water mark; whereas the part of the chain on the Anglesey side extended no further than the apex of the suspension pier.

Process used in taking over the first Suspension Chain, of which the remaining fifteen were a mere repetition.

On Tuesday, the 26th of April 1825, the first chain (i. e. the curved part thereof) of this stupendous work was thrown over the straits of Menai; the day was calm and highly propitious for the purpose.

An immense concourse of persons, of all ranks, began to assemble on the Anglesey and Carnarvonshire shores about twelve o'clock at noon, to witness a scene which our ancestors had never contemplated.

Mr. Telford attended, to see this part of his grand scheme effected.

Among the spectators were—Sir Robert Williams, Lady Williams, and family; Lord and Lady Boston, and family; Colonel Peacocke; Major Hampton, and family; John Williams, Esq., and family, Trosyrafon; W. Wynne Sparrow, Esq., and family, Red Hill; John Price, Esq., Plas Cadnant; Hugh Evans, Esq., and family, Henblas; Rev. H. Rowlands, Plasgwyn; Rev. R. Williams; Rev. P. B. Williams; Rev. J. Hamer; Rev. Ellis Roberts; Rev. Hugh Price; Rev. E. Jones; Thomas Jones, Esq., and family, Cromlech; Samuel Worthington, Esq., and family, &c. &c.

Numerous pleasure-boats, arrayed in all their gaudy colours, were seen 'gliding, in envious pride, on Menai's proud waters.'

Precisely at half-past two o'clock, it being then about half-flood tide, the raft,* prepared for the occasion, stationed on the Carnarvonshire side, near Treborth Mill, which supported the part of the chain intended to be drawn over, began to move gradually from its moorings, towed by four boats, with the assistance of the tide, to the centre of the

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* 450 feet long and 6 feet wide.

river, between the two grand piers; when the raft was properly adjusted, and brought to its ultimate situation, it was made fast to several buoys, anchored in the channel for that specific purpose. The whole of this arduous process was accomplished in twenty-five minutes.

The part of the chain, pending from the apex of the suspension pier, on the Carnarvonshire side, down nearly to high-water mark, was then made fast by a bolt to the part of the chain lying on the raft, which operation was completed in ten minutes.

The next process was fastening the other extremity of the chain, still lying on the raft, to two blocks, of immense size and power, for the purpose of hoisting it up to its intended station, the apex of the suspension pier, on the Anglesey side; the tension of the chain, at this time, was forty tons.

When the blocks were made secure to the chain (comprising twenty-five tons weight of iron), two capstans, and also two preventive capstans, commenced working, each capstan being propelled by thirty-two men.

To preserve an equal force and tension in the rotatory evolutions of the two principal capstans, two fifers played several enlivening tunes, to keep the workmen regular in their steps, for which purpose they had been previously trained.

At this critical and interesting juncture, the attention of every one present seemed riveted to the novel spectacle now presented to their anxious view; the chain rose majestically, and the gratifying sight was enthusiastically enjoyed by all present in 'breathless silence.'

At ten minutes before five o'clock the final bolt was fixed, which completed the whole line of chain, and the auspicious event was hailed by the hearty acclamations of the numerous spectators, joined by the vociferations of the workmen, which had a most delightful effect, from the reiteration of sound caused by the reverberation of the rocks on the opposite banks of the river.

Not the least accident, delay or failure occurred in any department during the whole operation, which does infinite credit to every individual engaged in the grand work.

From the casting off of the raft to the uniting of the chain, took up only two hours and twenty minutes, which appears truly astonishing, when the magnitude of the work is considered, and which could be appreciated by those only who had an opportunity of viewing it,—a work differing, in sublimity of design, from every other bridge; and which, undeniably, has not its equal in the known world.

Upon the completion of the chain, three of the workmen, viz. Hugh Davies, stonemason, William Williams, labourer, and John Williams, carpenter, had the temerity to pass along the upper surface of the chain, which forms a curvature of five hundred and ninety feet. The versed sine of the arch is forty-three feet.

On the termination of the day's proceedings, each workman (about one hundred and fifty in number) was regaled, by order of the Right Honourable the Parliamentary Commissioners of the Holyhead Road Improvements, with a quart of *Cwrw da.*

Thus concluded a day, which linked the reciprocal interests of the counties of Anglesey and Carnarvon in a union, which, 'it is devoutly to be wished,' will never be broken.

The ancient British name of Anglesey is '*Mon—Mam Cymru,*' the Mother of Wales; who will, by this uninterrupted communication, be more closely connected with her children than heretofore.

The other fifteen chains were taken over according to the following dates:—

2d chain - - - 28th April.

[On the 6th May, William Williams, labourer, after finishing his day's work, sat himself down quietly on the centre of the curved part of the upper suspension chain, with his feet resting on the one below it, and in that position actually went through the regular operation of making a pair of small shoes in the short space of two hours; which he afterwards sold for a sovereign. He was led to suppose that the shoes were purchased for public exhibition at the British Museum.]

3d Chain - -	May 7th.	10th Chain - - -	June 8th.
4th ditto - -	10th.	11th ditto - - -	10th.
5th ditto - -	13th.	12th ditto - - -	11th.
6th ditto - -	14th.	13th ditto - - -	15th.
7th ditto - -	21st.	14th ditto - - -	21st.
8th ditto - -	24th.	15th ditto - - -	28th.
9th ditto - -	June 4th.		

Taking over the last or Sixteenth Chain.

On Saturday, the 9th of July 1825, the last suspension chain of this truly marvellous and sublime work was taken over, which completed the entire line of suspension.

The anxiety felt by many to witness a spectacle so novel and interesting had drawn together numerous persons of all ranks, from every part of the United Kingdom, in addition to those resident within thirty miles of the spot.

The weather was particularly fine, the sun shone forth in all its wonted splendour, the shores were covered with innumerable spectators, and the river was elegantly studded with pleasure-boats, adorned with flags 'of every hue.'

'Smooth as a mirror was the deep,
'Save Zephyr, all the winds asleep.'

The same mechanical process was pursued in taking the chain over as that stated in a former account (*vide* page 574) only, with this difference, the workmen having acquired by practice an increased degree of adroitness, this (the last) chain was got over and the bolt fixed in one hour and thirty minutes; being a saving (in time) of fifty minutes compared with the first chain, which took up two hours and twenty minutes (*vide* page 575).

On fixing the final bolt, a band of music descended from the top of the Suspension Pier, on the Anglesey side, to a scaffolding, erected for that purpose, on the centre of the curved part of the chains (which form an inverted rainbow), and there played the national

air of 'God save the King,' amid the cheering and exultation of the numerous spectators on the opposite shores; 'and loud and many were the acclamations of the admiring multitude.'

The workmen were then arranged and marched (accompanied by music) in Indian file, on a platform resting on the two lowest centre chains, from the Anglesey to the Carnarvonshire side, along the curvature of the chain, and back again; which had a most picturesque effect from the sea-shore, the altitude diminishing the natural size of the objects, and giving them the imaginary appearance of 'aërial beings.' While this interesting scene was going forward, the St. David steam-packet, of Chester, D. Sarsfield, R. N., commander, passed under the chains, to a short distance beyond the bridge, towards the Swilly Rocks, then put about, and returned back again to its former station in the river, a little below Gorphwysfa wood.

This steam-packet had the distinguished honour of opening the navigation of the Strait, which had been closed, after giving due public notice, from the 21st of April preceding.

Of the Vertical Rods.

The sixteen suspension chains being all adjusted, and placed equidistant to each other, the vertical rods were fastened to them, the lower ends being firmly bolted to the iron sleepers (or transverse roadway bars), each vertical rod and sleeper being placed longitudinally, five feet apart. There are one hundred and eleven sleepers, to each of which are attached, transversely, four vertical rods, making the whole number of vertical rods in the line of suspension (*i. e.* between the two suspension piers) four hundred and forty-four.

Of the Suspended Roads, formed of Deal Planks.

The next process was laying the planks down across the sleepers, to form the suspended road-way, the main-spring of the whole project, the *ne plus ultra* of the grand scheme on which hung the entire fate of the whole enterprise.

Saturday, 24th September 1825, at five o'clock P. M., the first tier of planks on the roadways were rendered passable for the convenience of the workmen; on which occasion, after mounting a flag, to announce the happy event, a royal salute of twenty-one guns was fired at Craig-y-don, the hospitable seat of O. Williams, Esq. M. P. (one of the Commissioners), situate about a mile north-east of the bridge. His eldest son, T. P. Williams, Esq., M. P., gave £.4 to be distributed among the workmen.

The roadway consists of two carriage-roads, each twelve feet in breadth, with a foot-path, of four feet in breadth, in the centre between them, closed all the way by an iron railing on each side, to secure passengers from any accident which might otherwise occur in cases of horses proving restive; and it also affords personal protection from carriages or horned cattle passing along the road-way.

Three tiers of deal planks form the flooring of the roadway. The lowest tier of planks is three inches thick; the second tier, two inches thick; both laid down longitudinally, as the road runs. The third, or upper tier, two inches thick, is laid transversely, to the

width of eight feet, with side guides, made of African oak, to keep the carriage wheels clear from injuring the vertical rods.

The form of the suspended roadway is somewhat convex, rising gradually from the ends to three feet high at the centre, which gives it a most graceful appearance when viewed in front; it resembles a kind of eyebrow curve.

Here it is proper to make a momentary digression to state, that while the ferry-boats formed the only communication between Anglesey and Carnarvonshire, at Bangor Ferry, three quarters of an hour were usually consumed in the irksome process of unloading the coach, shipping the passengers, luggage and parcels, into an open ferry-boat, crossing the channel, and then unshipping again; and lastly, re-loading a second coach, to take on the passengers, &c.

But, independent of the inconvenience, interruption and loss of time, few persons, except those who have undergone the ordeal, are aware of the unpleasant sensation experienced by inside passengers, on their arrival at Bangor Ferry, being forced to quit a warm berth, whether by day, or in the dreary dead of the night, and unavoidably exposed to (frequently) a tremendous heavy rolling sea, with terrific waves washing into the boat, and tossing it about fore and aft, so as to alarm even the bold and daring spirit of an experienced seaman; or, perchance, forced to endure the unpleasant effects of a drenching shower of rain, 'the pelting of the pitiless storm,' with other vicissitudes of inclement weather; or which was a circumstance of very common occurrence, the probability of a wet jacket, either from rain or sea-water, for the remainder of the journey.

Such annoyances, miseries and perplexities as those just described speak volumes; and have, for ages past, shewn the actual necessity of doing away with such a public nuisance.

An antidote has at last, by the ingenuity of Mr. Telford's enlightened mind, been fortunately discovered and now brought into action, which will prove an irrefragable elucidation of the decided convenience, safety and gain in time effected by the erection of this (to say the least of it) useful bridge.

The ferry was the private property of the Plas Isa' family, of Conway, who held it for time immemorial, although they possessed no written document to shew how the family first became possessed of it. Soon after the building of the bridge had commenced, a certain sum was offered on the part of Government to the guardians of Miss Williams, the heiress, who was at that time under age, but which was not thought by them equivalent to its real value. Government had therefore no alternative left but to bring the question before a regular jury. Accordingly, at the Spring Assizes held at Beaumaris, March 4th, 1820, the question for an equitable compensation for the value of the ferry was argued by counsel, before Judge Leycester and a special jury; when the latter, after taking an average of the annual returns for the twelve years preceding, amounting to £.885. 18. per annum, awarded, allowing at the rate of thirty years' purchase, the sum of £.26,557, which sum was paid by Government to Sir D. Erskine, in right of his Lady (formerly Miss Williams, of Plas Isa'), on the day the Menai Bridge was opened.

On the night previous to the opening of the bridge, a notice was sent to the ferrymen, that as soon as the mail-coach had passed over the bridge, the ferry-boats were to cease plying, and the ferrymen's services were from that moment no longer required,—an event that deserves to be recorded in *letters of gold*.

FINAL OPENING of the BRIDGE, for the Accommodation of the Public.

On Monday the 30th of January 1826, this stupendous, pre-eminent and singularly unique structure was opened to the public, at thirty-five minutes after one o'clock A. M. by the Royal London and Holyhead mail-coach, conveying the London mail-bag for Dublin; David Davies, coachman; William Read, guard.

Mr. W. A. Provis, the resident engineer, had received instructions from the Commissioners to meet the London down mail at Bangor, and there take charge of it across the bridge.

The mail-coach, on its way to the bridge, stopped at the cross-road near Bangor Ferry inn, and took up Mr. Akers, mail-coach superintendent; Mr. Hazeldine, the contractor for the iron-work; Mr. J. Provis, the superintendent for proving and examining it; Mr. Rhodes, the director of the iron and timber work; Messrs. J. and W. Wilson, sons of the contractor for the masonry; and as many more as could find room to sit or stand, or even procure a place to hang by.

Thus loaded, the mail-coach proceeded on about half a mile to the toll-gate, which was immediately thrown open, and, amidst the glare of lamps (a heavy gale of wind blowing at the time), it passed across the bridge in grand style—

'The high-mettled steeds, mantling their proud crescent necks,
'As if conscious of the triumphant achievement.'

The first private carriage that crossed was that of Augustus Elliot Fuller, Esq., one of the Commissioners, drawn by four beautiful greys.

The second private carriage was Mr. Telford's, in which sat Sir Henry Parnell, Bart., and himself.

The first stage-coach was the Pilot, Bangor and Carnarvon day-coach.

The first London stage-coach was the Oxonian.

After these, the carriage of Sir D. Erskine, Bart., late proprietor of the ferry, drawn by four elegant greys, decorated with ribbons, followed by numerous gentlemen's carriages, landaus, gigs, cars, poney-sociables, &c. &c., upwards of one hundred and thirty in number, and horsemen innumerable.

By the particular and modest request of Mr. Telford, the architect, a regular and splendid procession, as at first intended, was dispensed with, to the serious disappointment of at least five thousand persons, who had assembled on this memorable occasion.

The cloud of disappointment, however, soon dissipated, and the numerous pedestrians, among whom were several persons of the first distinction, from both counties, continued parading along the beautiful platform roadway for several hours. Joy, admiration and astonishment seemed depicted in every countenance on beholding the proportion,

symmetry and grandeur apparent to the most common observer in every part of this unrivalled structure.

During the morning the rain fell in torrents, but towards mid-day the weather cleared up, and the afternoon was fine. The wind, due south, blew fresh throughout the day, which caused a trifling, though scarcely perceptible, undulatory motion about the centre of the bridge. Horses of every description nevertheless passed over, without evincing the least shyness or timidity.

A royal standard was hoisted on each of the main piers, together with numerous other flags; one displayed the loyal motto of 'Long live the King.' Cannons were stationed on each side of the bridge, which continued firing at intervals the whole day. A band of music attended, for the entertainment of the company, changing its situation occasionally from one side of the bridge to the other.

When we reflect on the varied appearance of the numerous persons and objects present, the elegance of the equipages, the bold and sublime scenery of the country adjacent, and though last, not least, of the general public utility of this grand national work, it must be allowed that the *coup-d'œil* was most enchanting; it was, indeed, a proud day for Cambria.

Wednesday, 1st of February 1826, the first three-masted vessel that passed under the bridge was the ship Melantho, of Carnarvon, homeward bound from Liverpool, with all her spars up and sails set, commanded by Captain Lloyd, piloted by David Hughes, of Bangor. The Melantho had been stranded, a few months previously, at Llanddwyn, on the eastern extremity of the Menai Strait, but was afterwards purchased, repaired and fitted up at Carnarvon. Her top-masts were nearly as high as those of a frigate, and yet cleared twelve feet and a half below the centre of the road-way, as ascertained by Mr. Rhodes, the iron-master, by measurement.

An inconceivable number of foreigners, of the highest distinction and celebrity, came at various times to view, examine and witness the progress of this wonderful bridge, which seems to have excited the surprise and attention of the most scientific men in every quarter of the globe.

Casualties.

It could scarcely be expected, in a work of such magnitude and intricacy, that every species of casualty could possibly be prevented. Few, indeed, of the many hands employed were maimed; but it is a melancholy duty to state, that during the erection of the bridge, four workmen lost their valuable lives in the execution of their various employments, viz. J. Read, stone-mason, a Scotchman; David Roberts, stone-mason, and Robert Roberts, carpenter, Welshmen; and John Key, stone-mason, an Englishman. In each instance, it is to be regretted, owing to the want of common prudence on their own part; as every precaution was taken by the overlookers of the work to prevent, as far as possible, any fatal occurrence.

Thus by a singular coincidence, each distinct branch of Great Britain has contributed its quota in the fatal list of casualties.

Conclusion.

This national and splendid specimen of British architecture will be a lasting monument to the discernment of the present Government, for having called into requisition the transcendent talents of Mr. Telford, who has thus, by a positive proof of superior scientific knowledge and taste, signalized himself, in this line, the first architect of the age.

The skilful manner in which the various concomitant parts of this magnificent bridge have been executed will remain an indelible proof of the superior abilities of Mr. W. A. Provis, resident engineer; Mr. J. Provis, prover and examiner of the iron; Mr. J. Wilson, the contractor for the masonry; Mr. Hazeldine, the iron-founder; and Mr. T. Rhodes, the superintendent engineer of the iron and timber work.

In the former part of this pamphlet it was shewn, that it had been foretold, upwards of a century back, by Robin Ddû, that a bridge would be built over the river Menai.

A person who has lately seen and minutely examined this masterpiece of perfection has predicted that the Menai bridge will rank, in future ages, as the eighth wonder of the world.

'Ere Snowdon sinks down, or its cliffs rift asunder,
'Menai bridge will be rank'd as the world's eighth wonder.'

Dimensions of the Stone Work.

The height of each main pier is one hundred feet from high-water line to the level of the roadway. From thence to the apex of the suspending pier, fifty-three feet. The arches through which carriages, &c., pass are nine feet wide, and fifteen feet to the spring of the arches, where the lamps are placed. From the main piers to the toll-houses, the road falls at the rate of one foot in twenty-five. Each of the small piers, from high-water line to the spring of the arch, is sixty-five feet; the span of each arch is fifty-two feet six inches. The roads on the bridge consist of two carriage-ways, twelve feet each, with a footpath of four feet in the centre. The length of the suspended part of the platform or road is five hundred and fifty feet.

The toll-house on the Carnarvonshire side is considered, in design and execution, a masterly performance; and does equal credit to the architect and builder, Mr. Telford and Mr. Wilson.

The toll-house on the Anglesey side is perfectly unique, and is remarkable for its elegant solid stone roof.

Dimensions of the Iron Work.

The chains, sixteen in number, consist of five chain-bars in each length. Each chain-bar is (generally) ten feet long, three and a quarter inches wide, and one inch thick; with six chain-plates at each end, sixteen inches long by eight inches broad, and one inch thick; secured by two bolts at each joint, each bolt weighing fifty-six pounds. The total number of chain-bars in the cross section of the chain is eighty. The number of chain-bars (consisting of five bars to each length) in one chain is nine hundred and thirty-five; in the sixteen chains, fourteen thousand nine hundred and sixty. The entire length of

the chain, from the fastenings in the rocks, is one thousand seven hundred and ten feet. The number of chain-plates (which unite the chain-bars) in each chain is one thousand one hundred and twenty-two; in all, seventeen thousand nine hundred and fifty-two. The number of bolts in each chain is three hundred and seventy-four, in all, five thousand nine hundred and eighty-four. The vertical rods, an inch square (suspended from the chains), are placed five feet apart, and support the sleepers or roadway bars, which form the flooring of the roadway. The number of suspension-rods in each line is one hundred and ninety-nine; total in the four lines, seven hundred and ninety-six. The number of sleepers is one hundred and eleven. The number of trussed-rods and king-posts which (with the sleepers) support the suspended part of the road is, of each, two hundred and twenty-two; in all four hundred and forty-four.

Weight of the Iron.

	lbs. weight.
64 large chain-bars, 7½ feet long, 4 inches wide, and 1½ inch thick, each bar weighing 150 lbs., multiplied by 5, makes	48,000
384 large chain-plates, 18 inches long, 10 inches broad, and 1½ inch thick, each weighing 75 lbs.	28,800
128 large bolts, each weighing 126 lbs.	16,128
123 chain-bars, 10 feet long, 3¼ inches wide, and 1 inch thick, each weighing 124 lbs., multiplied by 5, makes	76,260
738 chain-plates, 16 inches long, 8 inches broad, and 1 inch thick, each weighing 32 lbs.	23,616
246 bolts, each weighing 56 lbs.	13,776
597 connecting rods and bolts, each weighing 37 lbs.	16,119
16 steadying ties, each weighing 1,225 lbs.	19,600
Total weight of one chain (making 121 tons, 299 lbs.)	242,299
2 cast-iron plates under the saddles, each weighing 46,080 lbs.	92,160
8 saddles, each weighing 3,248 lbs.	25,984
20 tie-bars for the saddles, 20 feet long by 3 inches square, each weighing 600 lbs.	12,000
64 rollers, each weighing 335 lbs.	21,440
16 guide-plates and brass bushes, each weighing 373 lbs.	5,968
199 suspension-rods, averaging 33½ feet in length by 1 inch square, each rod weighing 111 lbs. multiplied by 4, makes	88,356
111 sleepers, each weighing 334 lbs.	37,074
222 trussed rods, each weighing 40 lbs.	8,880
222 king-posts, each weighing 7 lbs.	1,554
Anglesey side — 98 side-rails, each weighing 80 lbs.	7,840
Anglesey side — 98 footway-rails, each weighing 50 lbs.	4,900
Suspended part, 222 side-rails, each weighing 10 lbs.	14,430
Carnarvonshire side. — 74 side-rails, each weighing 65 lbs.	5,920
Carnarvonshire side. — 74 footway-rails, each weighing 50 lbs.	3,700
Carried forward	330,206

		lbs. weight.
	Brought over	330,206
	6 cast-iron frames for the fastenings in the rocks, each weighing 2,240 lbs.	13,440
	24 round bolts, 9 feet by 6 inches, each weighing 444 lbs.	10,656
Anglesey side	78 side road-rails, each weighing 80 lbs.	6,240
	24 centre road-rails, each weighing 50 lbs.	1,200
	78 cast-iron stanchions, to support the rails, each weighing 176 lbs.	13,728
	24 short stanchions, each weighing 100 lbs.	2,400
	39 hand-rails, each weighing 104 lbs.	4,056
Carnarvonshire side.	38 side road-rails, each weighing 80 lbs.	3,040
	40 cast-iron stanchions, each weighing 176 lbs.	7,040
	38 hand-rails, each weighing 104 lbs.	3,952
	484 cast-iron parapet-rails, each weighing 31 lbs.	15,004
	4 sets of cast-iron saddles (near the Anglesey toll-gate), each weighing 2,016 lbs.	8,064
	8 gate-posts, each weighing 533 lbs.	4,264
	4 toll-gates, each weighing 325 lbs.	1,300
	2 lamp-posts, each weighing 300 lbs.	600
	12 tie-bars in the pier-arches, each weighing 533 lbs.	6,296
	32 cast-iron saddles (above the toll-house on the Carnarvonshire side) each weighing 416 lbs.	13,312
	4 plates under the last-mentioned saddles, each weighing 900 lbs.	3,600
	240 segment saddle-bars on the piers, and near the Anglesey toll-gate, each weighing 200 lbs.	48,000
		496,498
	Total weight of the 16 chains (1,938 tons, 784 lbs.)	3,876,784
	Total weight of iron	4,373,282

Making, in all, 2,186 tons, 1,282 lbs.

N. B.—The above calculations are made from Mr. Samuel Penn's Tables of the Weight of Iron.

Tolls taken at the Menai Bridge.

	s.	d.
For every stage-coach	2	6
For every post-chaise, coach, landau, berlin, barouche, or other such carriage, with four wheels and four horses	3	–
Ditto - - ditto - - with four wheels and two horses	2	–
For every waggon, wain, or other such carriage, with four wheels	1	–
For every cart or other carriage, with two wheels	–	6
For every horse, mule or ass, not drawing any carriage	–	2

	s.	d.
For every foot-passenger - - - - - - - - - - - -	–	1
For every drove of oxen, cows or neat cattle, per score - - - - -	1	–
For every drove of hogs, calves, sheep or lambs, per score - - - - -	–	6

The Tolls produced last year about £. 1,200.

Additions.

The total sum expended by Government in the erection of the Menai Suspension Bridge, including therein the formation of a considerable embankment on the Anglesey side, a new line of road (of about half a mile in length on the Carnarvonshire side), and the toll-houses, amounted to £. 120,000.

The fastenings of the main chains in the rocks may be seen, on application to Mr. Fisher, inspector of the bridge, at the toll-house, on the Anglesey side.

Appendix (P.)

CENTERING FOR GLOUCESTER OVER BRIDGE.

Extract of Letter from Mr. *Cargill* to Mr. *Telford*, dated Gloucester, March 26, 1832.

In constructing the centering (*see* Plate 63) for this bridge, I first laid a platform perfectly level and a little larger than the centering which was to be made; I then struck it out the full size upon this platform, firmly fixing centres to the different radii. The timber was Dantzic, being much harder and of larger dimensions than Memel, and mostly fifteen inches square. The iron straps were also of the best iron. The piles upon which the centre was to stand were then driven; they were of Memel timber, with wrought-iron shoes, and caps framed upon their tops to the proper height; upon these caps were laid another tier of beams lengthways of the centre one under each rib; upon these beams were fixed the wedges, which were of three thicknesses; the bottom one being bolted down to these beams, the tongue (or driving piece in the middle) being of oak and well hooped at the driving end, the top side of the upper piece was laid perfectly level and strait, both transverse and longitudinally; the wedges were rubbed with soft soap and black lead before they were laid upon each other. Each rib of the centre was then brought and put together upon a scaffold made upon the top of these wedge-pieces, and lifted up whole by means of two barges in the river and two cranes on shore. The scaffold was extended thirty feet beyond the striking end of the wedges to lay the last ribs upon previous to raising, also to stand upon for finally striking. After the ribs were properly braced, they were covered with the four-inch sheeting piles which had been used in

the cofferdams. That this centre was well suited to the purpose is known by its not sinking more than one inch when we keyed the arch. My greatest dread was the coal-boats which trade on the Ledbury Canal, forced adrift by floods in the Severn, and striking against the centre before we could close the arch. To prevent mischief of this kind, I drove the piles for extending the up-stream side of the scaffold (or rather of the platform on which it was originally constructed) very firmly into the clay, so that they might resist the stroke of a boat before she could touch any of the supports of the centering.

In the month of December, when within twenty feet of closing the arch, a very high flood being in the Severn, two of these boats loaded with coal came adrift, struck the outside piles, which were Memel logs, broke two of them, then sunk against the main bearing piles which supported the centre, one boat upon the top of the other. These boats, being seventy feet long, raised a considerable head of water over them, and lay there until the flood subsided, which was many weeks; had not these upper guard-piles weakened the shock, I believe the whole centre and arch would have been destroyed.

When the spandril-walls were built up to two courses below the crown of the arch, and the internal brick walls to the same height,—we struck the centre, which was done by placing beams upon the top of the work, directly over the ends of the wedges; to these beams successively was fixed a tackle, to which (at the lower end) was slung the heavy ram (with which we drove the piles) with tail-ropes fixed to it, and slung exactly, so as to strike in its swinging (when pulled back) the driving end of the tongue piece of the wedge. This ram of 12 cwt., when pulled back by eight men, and two men to pull it forward, gave a most tremendous blow, yet twenty or thirty blows were requisite before we could perceive the wedges to move; but after they once moved, they slid themselves, and we put in pieces to stop them going farther than was required. The whole time of striking, I think, did not exceed three hours, although we had the ram to remove and the tackle to refix at every set of wedges. I was much afraid that no force we could bring against these wedges would move them under such a weight as the entire arch, they being themselves a heavy body, and it was no small joy to see this effected so easily. I am persuaded no wedges placed in the usual way could have been disengaged, as no force could be brought to act upon them sufficient for that purpose. We then disengaged the covering, (which it will be remembered was composed of sleeting piles from the cofferdam), and let down the ribs as they were put up, took them to pieces and carried them ashore. The whole of the bearing piles were then drawn by two levers (each made of two forty-feet logs) and strong chains; every pile was drawn, and although the expense was considerable, they paid well for the labour.

APPENDIX (Q.)

SHIP CANAL for the JUNCTION of the ENGLISH and BRISTOL CHANNELS.

REPORTS of Mr. *Telford* and Captain *Nicholls*.

REPORT OF THOMAS TELFORD.

ENGLISH AND BRISTOL CHANNELS SHIP CANAL.

IN consequence of instructions from the promoters of the scheme for the above-mentioned Ship Canal, transmitted to me by the chairman of the Committee, John Bent, Esq. M. P., dated the 14th July last, I immediately made arrangements, and proceeded to perambulate the districts of country through which it was proposed to carry the canal. For making the field surveys and sections, and for collecting the necessary data under my direction, I selected Mr. James Green, of Exeter, who, with extensive practice in civil engineering, combines a thorough knowledge of the localities.

With Mr. Green, therefore, I examined the district which composes the comparatively narrow isthmus of the Cornish and Devon peninsula; with this was included the several valleys that fall in from the eastern and western sides of the main valley, which lies in a north and south direction. This was done, in order to acquire a knowledge of the quality and shape of the ground, over which a large canal might be carried, and the probability of acquiring a sufficient supply of water for the purposes of an extensive intercourse, such as would justify so great an undertaking.

With similar views, the shores of the English and Bristol Channels were examined, for the fittest terminations for a navigation of the before-mentioned description, in conjunction with extensive asylum harbours.

Having satisfied myself with respect to the leading features of the measure, I made out written instructions for the survey, and engaged Mr. Green to proceed with all practicable despatch. I then returned to London, and made my preliminary Report, on the 2d of August. This Report (Appendix, page 592) having satisfied the Committee of the practicability and feasibility of the scheme, I received directions to proceed with due energy, so as to have the necessary documents in readiness to comply with the Standing Orders of Parliament.

I was likewise authorized to procure a Report from an able and experienced seaman, of known character in his profession, as to the proposed terminations on the shores of the English and Bristol Channels; for this purpose, I selected Captain George Nicholls, long well known in the Honourable East India Company's Service, whose talents and fitness were fully vouched by one of the respectable Directors (Appendix, page 594). The able and laborious Report of Captain Nicholls is better evidence of his qualifications

than any commendations I can bestow. After his repeated surveys and investigations, I attended him to each shore, and his explanations fully convinced me that the points selected were peculiarly favourable, and I benefited by his judicious observations in sundry matters in which my want of experience in nautical affairs would have left me in doubt. He has bestowed much pains in acquiring and arranging very important matter, not only in regard to the approach and departure of vessels, but the great saving of time and expense which would follow from using this canal navigation, and likewise the probable revenue which it may be fairly expected to produce. The data upon which he founds his statements are certainly drawn from the most authentic sources to which he could have access.

Conceiving myself, therefore, relieved from all that regards tideway affairs and revenue, I shall proceed,

I. To describe the line of the intended canal, its several levels, lockage, and other works.

II. Explain what regards supplying the canal with water.

III. Describe the piers, docks and harbours, proposed to be constructed on the shores of the English and Bristol Channels.

IV. Furnish an estimate of the expense of the canal, harbours and sundry works connected therewith.

V. Make some general observations.

I. *Line of Canal.*

This canal, and the works connected therewith, are intended to accommodate vessels of two hundred tons, when fully loaded; for this purpose fifteen feet depth of water is required, with locks one hundred and twenty-five feet in length, and thirty feet in breadth, which will also admit vessels of still greater tonnage, when light or partly loaded (*see* Appendix, page 595).

The rise of each lock to be eight feet, and thirty in number, on each side of the summit. And as the canal will be ninety-five feet wide at top water, vessels of two hundred tons, being only twenty-five and a half feet in breadth to the extremity of their channels, and there being two towing-paths, they may pass each other, without interruption, in every part of the line. Under these circumstances, the line of canal I am about to describe has been selected and surveyed.

Upon the shore of the English Channel, the canal line commences at Beer Harbour (described under the third head of this Report), where five locks, of eight feet rise each, are placed in the mass of White Cliff; from thence the line passes, by some deep cutting, on the upper or western side of the village of Seaton; and proceeds upon one level, in nearly a strait direction, for a distance of about five miles, across the river Colly, and past

the villages of Whiteford and Woodhayne. At a little north of Kilmington the lockage commences, and the line, bending gently westward, crosses the Yarty river and valley; it afterwards continues to near Clocombe, and from thence proceeds by lockage, up the western side of the river Axe, to the commencement of the summit level near Titherleigh, having, in this part of its course, crossed the Wambrook stream and small valley.

In crossing the before-mentioned streams, proper aqueducts have been provided for passing the flood-waters.

From Beer Harbour to this place the distance is eleven and three quarter miles, and, excepting the deep cutting at Seaton, the ground is sufficiently favourable, and no works of unusual magnitude are required.

Upon the summit level, for the distance of about a mile and a half, no obstacle occurs, but in the course of the next two miles, there is some heavy deep cutting, which cannot be avoided, unless by increasing the lockage and shortening the summit, both very objectionable. From this place to the northern termination of the summit level, the ground is favourable; its whole length is twelve and a half miles.

From this north end of the summit level, the lockage down to the river Tone, at Currey, is as regularly distributed as the shape of the ground will admit. The Tone valley and river are passed by an embankment and aqueduct, at a height to admit a free passage for the navigation and flood-waters.

Between the river Tone and Bridgewater, only two locks are required, and, excepting a circuity to avoid some high ground, the line is favourable.

The town of Bridgewater standing upon the termination of a considerable ridge of land, some deep cutting is unavoidable; but the line is chosen so as to interfere with only a few houses, of comparatively small value, and to cross only one street.

From Bridgewater to Coombwich the ground is remarkably suitable, being all level cutting, and very direct.

At Coombwich, I propose to construct a small basin and tide-lock, but instead of the general intercourse being forced to enter the river Parret at this place, and follow its circuitous course amongst irregular mud-banks, the canal line is continued about three and a half miles along level ground, to the south-west angle of Bridgewater Bay, at Stolford, where it will terminate in an extensive basin and artificial harbour, to be described under the third head.

From the northern extremity of the summit level to this place, the distance is twenty miles three furlongs. Of this distance, fifteen and a half miles have only two locks, and these are considerably to the south of Bridgewater. The total distance from Beer Harbour to Bridgewater Bay is forty-four miles five furlongs; the fall from the summit to high water, at an ordinary tide, in Bridgewater Bay, is two hundred and thirty-one feet; but by taking a different tide at Beer, the fall was found to be two hundred and thirty-three feet.

The ground along the canal line, consisting generally of clays, marls, or other substances which will retain water, appears (as far as could in the course of a hasty survey be ascertained) very suitable for canal operations.

At the northern end of the summit level, and also on the shore at and adjacent to Bridgewater Bay, there is abundance of stratified lias limestone, equally suitable as building stone and for mortar, which hardens in waterworks; a singular advantage, where so many locks, aqueducts, piers, &c., will be required.

II. *Supplying the Canal with Water.*

The general direction of the canal line is nearly north and south, the valley of the Axe forming the southern division, and those of the Tone and Parret the northern; but the river Axe, previous to reaching the summit level, turns, at almost a right angle, to the eastward, and there, embracing a great extent of country, with many collateral streams, affords a very favourable situation for a reservoir, to collect flood-waters, and accordingly, one of two hundred and seventeen acres has been surveyed, where there is ample country to fill it. From this reservoir a feeder will conduct the water into the summit level, and the population of the country through which it passes justifies making the greater part of it navigable for small boats; a small reservoir may also be constructed in the line of the feeder.

On the western side of the canal line, the Yarty valley proceeds far into the country, and its upper part branches to a very considerable width, embracing a sufficient extent to ensure an abundant supply of flood-water to a reservoir of one hundred and five acres; to conduct this, by an open feeder, for the whole of the way, would be too circuitous; but by driving a small heading through a ridge, the waters may be brought from the bottom of the Yarty reservoir into the Chardstock reservoir, and from it into the summit level; and it will be found advisable to make this feeder navigable for small boats.

For working the lower levels of the southern district, advantage may be taken of the Colly river, also the lower part of the river Yarty, and, if necessary, of the river Axe, there being few mills on the lower parts of these streams.

From the sources already described, such ample supplies may be obtained as to render it unnecessary to have recourse to any of the waters falling into the rivers Tone and Parret, which it is desirable to avoid, on account of the valuable purposes to which they are appropriated.

III. *Harbours, &c.*

With regard to harbours at the terminations of the canal, I shall commence with that of Beer, in the English Channel; its natural advantages are such, that it has always drawn public attention whenever the protection of shipping in this channel came under discussion; and its importance is certainly still further increased when considered as the termination of a ship canal.

Its merits, in a nautical view, are so fully discussed in the able Report of Captain Nicholls, that I have only to describe shortly the outlines of the intended artificial piers which it is necessary to construct.

Beer Harbour being naturally very effectually protected on the western side by a bold headland, it is proposed to defend it on the eastern side by an artificial pier, projected from White Cliff into twenty-four feet water at low-water spring-tides, which will require a length of pier of about two thousand five hundred feet; but as there is within the site of this outer pier, or rather breakwater, a ledge of rocks, which, if left uncovered, would be dangerous, I therefore propose to build an inner pier of about one thousand two hundred feet in length, and terminate it in fifteen feet water at low-water; this would effectually protect the inner harbour and the canal entrance. On the western side of the harbour, from Hall Point, I propose extending a pier about nine hundred feet, in order to check the in-run of the sea; this would terminate in twenty-four feet water at low-water of a spring-tide; there would thus be an outer harbour, sheltered by two pier-heads, where ships of twenty-feet draught of water might run into at all times of tide, while vessels of smaller draught, bound for the canal, might at all times pass within the inner pier, and at half-tide enter the canal basin; to obtain this basin, I propose forming the upper part of the bay into a floating-dock, with one pair of gates, to be opened at half-tide, for vessels to run in during the latter half of the flow, and pass out at the first half of the ebb. This dock having always fifteen feet of water would accommodate the canal vessels, which might pass up and down in regular succession through the locks, which would be constructed at the north-east angle along the before-mentioned White Cliff.

If constructed in the manner here described, both the purposes of a canal and asylum harbour would be accomplished, by inclosing about fifty acres.

For the construction of these extensive piers, the necessary excavation from White Cliff will afford the great mass of material to form the body of the work; a considerable part of this cliff consisting of a stone, harder even than Portland stone; and it thereby becomes advantageous that so much can be cut away within so short a distance.

To the Bristol Channel, it has been distinctly shown in Captain Nicholls's Report, that an excellent entrance may be had at the south-western angle of Bridgewater Bay, on the eastern extremity of the Wick Rocks, at a place called Stolford; this must unavoidably be a tide-harbour, protected by artificial piers, the harbour bottom to be excavated as much as practicable, at a moderate expense, below low water of a spring-tide. From the singular velocity with which the tides in the Bristol Channel flow, vessels, according to their draught of water, might then enter, at from one and a half to two hours' flood; and while waiting for this, it appears, from the before-mentioned Report, that there is good anchorage in the offing, where, in moderate weather, they would be perfectly safe; while in rough or stormy weather, Blue Anchor Bay to the west, and Penarth Point to the north-east, afford temporary asylums.

The protecting piers would, from the flatness of the shore and unusually great rise of tides, be very extensive, that is, each about three thousand feet, but they would then inclose about one hundred acres. From this harbour I propose to pass, by lockage, into a floating basin or dock, and from thence into the canal, by the same sort of arrangement as described for Beer. From this tide basin, the canal continues on one level past Coombwich, to a considerable way south of Bridgewater; indeed, with only two locks, it

(as has already been described) continues level quite across the Tone valley, a distance from the shore of upwards of fifteen miles.

At the Stolford termination there is a valley and small stream, the water of which may be collected, and if necessary be used for lockage, or for the use of the floating-dock, or scouring the harbour.

IV. *Estimate.*

	£.
1. Earth-work, including cuttings, embanking, puddling, on the whole of the main line, also to two lines of feeders, and four reservoirs - - - - - - - - -	575,798
2. Masonry to locks, bridges, aqueducts, culverts, reservoirs - -	602,346
3. Two very extensive entrance and asylum harbours, with their floating basins - - - - - - - - - -	424,100
4. Land, and damages, and fences, including compensation for mills	110,600
£.	1,712,844

V. *General Observations.*

From the foregoing statements, it is evident that the making a canal and harbours of proper dimensions is not only practicable, but that sundry circumstances are much in its favour. The soil is, in general, remarkably suitable for holding water. The lias limestone being found on the line is an important advantage. The entrance harbours seem to comprise all that is required for the object had in view; and the distribution of the canal levels, whether we regard the extensive lower levels, or that upon the summit, are very suitable for the purposes of the country through which the canal passes, while all the intercourse which is calculated on may be amply supplied with water. Therefore, as far as civil engineering is concerned, it is quite evident that a ship canal between the English and Bristol Channels is very practicable.

From the magnitude of the canal and harbour works, the expense is unavoidably very considerable; but as all expenditure is to be compared with the benefits and revenue to be derived from the improvement, if we are to judge from the data which have, with much care, been collected and arranged by Captain Nicholls, even this expenditure of £. 1,712,844 is fully justified by the annual income of £. 210,846. 12 *s.* 4 *d.*, which may be expected upon the completion of this new line of communication.

Having in my preliminary Report stated, that the harbour of Watchett had facilities which justified an investigation of its merits, and of a line of canal to be connected therewith, I consider it proper to state that a trial survey was made, the result of which was, that a ridge of land one hundred and fifty feet higher than the Chard summit intervenes between the Tone valley and that of the valley which terminates upon Watchett, which evidently renders that line quite impracticable.

London, 14th December 1824. *Thomas Telford.*

Appendix referred to p. 586.

ENGLISH AND BRISTOL CHANNELS SHIP CANAL.

Preliminary Report.

Agreeably to the Committee's instructions, dated the 13th ult., I proceeded to the summit of the country through which the intended canal would pass; and, after having carefully examined the districts adjacent to and connected with this summit, I proceeded down the valley of the Axe to the sea-shore at Seaton and Beer, on the English Channel. I next examined the several extensive collateral valleys, which descend towards that of the Axe and the English Channel.

I afterwards commenced a perambulation on the northern side of the Chard summit, and made a general inspection of the rivers Parret and Tone, to the shores of the Bristol Channel.

In performing this general survey, I derived much advantage from levels, which, although taken by Mr. Green for a canal of a very different description, yet enabled me to ascertain numerous relative points in various and very distant parts of the country.

By other suggestions from respectable quarters, I was induced to extend my inspection over a district not hitherto explored, with a view of inland navigation; I mean that which is situated on the western side of the Quantoch Hills, and terminates on the shore of the Bristol Channel at and adjacent to Watchett.

Until the surveys I have directed to be made are completed, I cannot enter into details respecting the precise lines which it will be most advisable to adopt, or the amount of expense which will be incurred; but, as a General Preliminary Report, I am enabled to state, that in regard to the practicability of constructing a safe and commodious canal navigation between the English and Bristol Channels, capable of admitting ships of one hundred and twenty to two hundred tons burthen, I am convinced, from experience in similar cases, that no obstacles exist but what may, at a comparatively moderate expense, be overcome.

In a general point of view, the chief objects to be attended to are:

I. The crossing of the summit of the country.

II. The procuring upon the summit level a plentiful supply of water.

III. The direction which the general line of canal shall take from the summit to the English Channel, and its termination there.

IV. The best direction to be taken from the northern extremity of the summit to the Bristol Channel.

I. As respects the summit level, the pass immediately east of the town of Chard in Somersetshire is decidedly the most advisable, and the lowest part of that pass should,

of course, be taken. By the survey formerly made, the summit level is only two and a half miles in length, but, after carefully examining the country, I am of opinion that this summit level should be extended much farther each way from Chard. Until correct levels have been taken, I cannot determine the precise length, but from the points ascertained by Mr. Green's levels, I think it may be made at least ten miles. This, with judicious management, would itself be an extensive reservoir.

II. This very considerable length of summit level embraces a great range of the high lands which occupy the country to the westward, which, being intersected by sundry considerable collateral valleys, affords ample opportunities of supplying it with water for the purposes of lockage, &c., in both directions; the waters of the Wambrook stream, and those of the extensive Yarty valley, may be brought in from the westward, and the flood-waters of the upper part of the river Axe may be brought in from the eastward; all into the summit level. Additional supplies of water may be procured from other sources, say the Coly valley and river, which, although they cannot, with conveniency, be brought into the summit level, will be extremely useful in providing for evaporation and leakage, as well as the increased consumption by the lower lockage.

III. From the southern extremity of the summit level, the canal will descend by lockage properly distributed along the western side of the river Axe, and the village of Seaton to the north-east angle of Beer Harbour, into which the canal will descend by means of locks placed in the mass of rocky cliffs, which may be conveniently excavated for this purpose, and to form extensive protecting and landing piers.

By keeping on the western side of Seaton village, its connection with the beach is left uninterrupted, the large mass of loose shingle beach, and also the steep crumbling marly banks along the shore, are avoided, and the canal introduced at once into the north-east angle of the harbour to be formed at Beer, leaving the rest of the harbour, and the whole of the Seaton Bay, for the purposes of a roadstead.

These cliffs at Beer will be found to be very advantageous, by affording a firm foundation for locks, producing materials for backing them, and for the hearting or body of the protecting piers and necessary wharf-walls; while the harder facing-stone can be brought by sea.

It is well known that Beer Harbour is already effectually protected from the most prevalent winds; and from the others, which are to the southward of either east or west, it may, by artificial piers, be made as secure as any harbour into which the tide is freely admitted; while the depth of water to be obtained is only limited by the amount of expense it may be judged advisable to incur; what I shall have in view in forming the plan and estimate will be to obtain twenty feet of water within the pier-heads at low water of a spring-tide. The access to the harbour is upon clear ground, and there is no prospect of its being incommoded by mud, sand or shingle.

Upon the whole, it appears that Beer Harbour is a very suitable place for the termination of a ship canal, and as an asylum for ships navigating the English Channel.

IV. To the northward of the town of Chard, instead of immediately commencing lockage, and carrying the canal down the bottom of the valley, and passing across the soft lands which compose the alluvial banks of the river Parret, and which unavoidably leads the line into a very circuitous direction by the town of Langport, the extension of the summit level, which has been here referred to, preserves it in the high lands by Broadway and Bickenhall towards Henlade lime quarries; and near this place, in whatever direction the line may afterwards proceed, the lockage must commence.

If, after proper surveys have been made, it proves most advisable to carry the canal by Bridgewater to the lower part of the river Parret, it will only remain to choose the most direct line to and across the lower parts of the Tone valley, and by the town of Bridgewater to the deep channel at the Coombwich Reach.

But if, after full investigation, the Port of Watchett is found to be the most advantageous entrance into the Bristol Channel, the canal line would probably pass near to Thurlbear, and cross the valley of the Tone between Taunton and Wellington; and from thence pass either to the east or west of Sandhill Park, the seat of Sir Thomas Lethbridge, Bart., and, after crossing a rib of high land at some distance to the north of Sandhill Park, proceed down a rich valley to the Port of Watchett.

The Port of Watchett possesses many natural advantages, and there does not appear to be any obstacles but may be remedied by artificial means. It is very accessible to and from a part of the Bristol Channel, which is without all the extensive sand-banks; and vessels have, of course, the advantage of being immediately in the tideway. The shore presents excellent foundations, also materials for extensive piers, and wet and dry docks, while the adjacent country produces an ample supply of water for lockage and other purposes; and the whole being the property of a nobleman who is friendly to the scheme, and to national improvements in general, every necessary facility would be afforded.

When the surveys I have directed to be made have been completed, a full and impartial comparison will be made between this port and the mouth of the river Parret; but it is beyond a doubt that proper access with the Bristol Channel can be obtained at one of those places.

London, 2 August 1824. *Thomas Telford.*

APPENDIX referred to, page 586.

Sir, East India House, 13 November 1824.

IN answer to your inquiry, as to my knowledge of Captain George Nicholls, I have great satisfaction in saying, that I believe him to be a man of high honour, excellent talent, and perfectly master of his profession. I have been intimately acquainted with Captain Nicholls about eighteen years; he served with me in the responsible situation of

chief officer of one of the East India Company's twelve hundred ton ships, in which capacity I first had an opportunity of appreciating his qualifications. He has since commanded a ship in the same service, and, in my opinion, stood conspicuous as a gentleman, an officer, and a seaman.

I am, Sir,
Your obedient Servant,
To Thos. Telford, Esq. (signed) *John Loch.*

APPENDIX referred to, page 587.

DIMENSIONS OF VESSELS.

DOCUMENT furnished by the MASTER and WARDENS of the TRINITY HOUSE to a Committee of the House of Commons, March 27th, 1800.

Tonnage. Tons.	Breadth in Feet.	Length of Keel in Feet.	Draught loaded in Feet.	Mode of Rigging.
100	19	53	10 –	Sloop.
150	22	59	12 4	Snows or Ships.
200	24	65	14 –	- ditto.
250	25	75	15 –	- ditto.
300	26 ½	80	16 –	- ditto.

STATEMENT by Mr. *Edward Nicholls*, one of the PILOTS of the TRINITY HOUSE.

Tonnage.	Length of Vessels.	Breadth.	Projection of Bowsprit.	Total Length.
	ft. in.	ft. in.	ft.	ft. in.
200	89 6	23 –	27	116 6
250	93 –	29 9	30	123 –
300	100 –	27 10	34	134 –

DIMENSIONS, taken from a Draught furnished by an eminent Ship-builder.

200 Ton Ship.

	feet.
Length from the Tafferel to the extremity of the Knee of the Head - -	84
Ditto - - ditto to the end of the Bowsprit - - - -	100
Ditto, from end of Main-boom to Jib-boom when run in - - -	118
Ditto - - ditto - - ditto - - when run out - - -	134
Extreme breadth over Channels - - - - - - - - -	25
Draught of Water when loaded - - - - - - - - -	12

REPORT OF CAPTAIN NICHOLLS.

ENGLISH AND BRISTOL CHANNELS SHIP CANAL.

To *Thomas Telford*, Esq.

Sir,

I HAVE now to state to you, that in conformity to the instructions conveyed to me in your letter of the 31st August, I proceeded, on the 6th September, to examine the several places therein pointed out. In consequence, also, of written communications to that effect, and of interviews which I subsequently had with you in London, on the 28th and 29th September, I went, on the 3d of the following month, to examine Uphill Bay, and the coast thence on to the entrance of the Parret, and to the westward of that river. In the progress of these surveys, I have availed myself of all the assistance that could be derived from pilots and others conversant with the coasts, as well as of our best charts and books of sailing directions.

In consequence, likewise, of the wish expressed by you, and of some communications which I have had with Messrs. King and Lukin, and Mr. Clarke, solicitors to the undertaking, I have visited the chief ports on the south coast of Wales; and there, as well as along the projected line, I have collected the best information that could be obtained with reference to the uses of the proposed canal.

The matters which have thus been referred to me for examination and report may be classed under two heads, each perfectly distinct from the other. The one is purely a nautical question, being a survey for the purpose of ascertaining suitable points, on the coasts of the English and Bristol Channels, for the terminations of the canal. The second head of inquiry comprises matters, the rightly disposing of which will enable the promoters of the undertaking to form an estimate of the advantages likely to result from it, and the extent to which it may reasonably be expected that the canal will be used for the general purposes of navigation and commerce.

I think it will be advantageous to treat of these two subjects separately. I will begin with the nautical part of the question; and for the information of the committee of subscribers to the proposed ship canal, I now beg to make the following Report:—

On considering my instructions, it appears that I am required,

I.—To examine and describe Bridgewater Bay and the river Parret; and, generally, such other points to the eastward and westward thereof, along the south coast of the Bristol Channel, as shall appear to me to afford suitable facilities for an entrance to the proposed canal.

II.—To state my opinion, together with the reasons at length on which the same is founded, as to which of the several places so examined by me, in a nautical point of view, would, on the whole, be the fittest termination for the proposed canal in the Bristol Channel.

III.—To examine and describe Seaton Bay and Beer Harbour, in the English Channel, and to be "extremely particular" in reporting whether the works which it is proposed to construct at the latter place will afford adequate shelter to vessels using the canal.

I will take these several objects of inquiry in the order in which they are above set down; and if, in discussing them, I shall be led into details tedious or minute, I entreat that this may be imputed to the sense which I entertain of the great importance of the commission intrusted to me, and to my solicitude not to leave any material circumstance unexamined and unexplained.

I.

Under the first division of the subject, I propose to confine my inquiries to the line of coast at and between Uphill Bay on the east, and Minehead on the west; these places, and the intermediate coast, appearing to me to be alone suitable for the object in view. I will begin with Uphill Bay.

Uphill or *Weston Bay* is directly opposite to the Steep Holmes. It is formed by a lofty projecting headland, called Brean Down, on the south-west side, and a bold rocky point of considerable elevation, called Anchor Point, on the north-east. Off this last point, and connected with it by a natural causeway, that dries at about two-thirds ebb, is a small islet called Brean Rock.

At high-water, Uphill Bay appears to recede very considerably within these headlands, and to afford pretty good shelter; but the bottom runs out very shallow from the back of the bay, and vessels drawing twelve or fourteen feet water must anchor so far in the offing, to lie afloat at low water, as to receive but little protection in this anchorage, excepting when the wind is off the land.

Vessels anchoring on the north side of Brean Down will find good shelter under it in southerly winds. There is anchorage, too, on its south side, where vessels will be well protected whilst the wind is at north or north-east; but on both sides, the bank or flat of the mud extends so far out as to prevent vessels from deriving that effectual shelter which so lofty a ridge of land would else afford; and both to the north and south of it, moreover, the anchorage is quite open to westerly winds.

Off the western extremity of Brean Down, a ledge of rocks extends out about a quarter of a mile, in the direction of the Steep Holmes. The rush of tide round this point is extremely

rapid, and when it blows hard from the westward or northward, the sea runs very heavy here; it would therefore, I am convinced, be quite impossible to construct a pier or breakwater off this point sufficient to protect vessels in westerly gales.

The river Axe empties itself into the south-east corner of Uphill Bay, close under the east end of Brean Down, at which point the hill rises up abruptly precipitous, and is here united to the low land within it by a flat narrow isthmus, only about a quarter of a mile across. This point appears to be more eligible for an entrance to the proposed canal than any other in the vicinity of Uphill Bay, as two openings might be formed here, one of them to the south of Brean Down, into what is called Berrow Bay, the other to the north, into Uphill Bay. This would give to vessels the advantage of entering or departing from the canal under shelter, either in northerly or southerly winds; but both entrances would be open to the westward.

Bridgewater Bay and the *River Parret.* On entering the Bristol Channel, and proceeding up it to the eastward, along the south shore, the first danger is the *Culver Sand,* which dries at about half ebb. It extends, nearly east and west, five miles, and is two miles broad, and may be said to form the northern boundary of Bridgewater Bay.

To the south-eastward of the Culver Sand is another sand-bank, called *the Gore,* which extends across the entrance of the river Parret, and is also dry at about half-tide. This sand runs out nearly due west from the shore, to the distance of about six miles, and terminates in a narrow spit.

There is good holding-ground, with from three to six fathoms at low water, all over Bridgewater Bay, and in the wide channel between the Gore and the Culver Sands, where vessels may anchor in moderate weather, or if the wind is in any direction off the land; but if it should set in to blow strong from the west or north-west, this anchorage is quite open and exposed.

Between the Gore Sand and an extensive bank of mud which skirts the southern shore and Stert Island, is the fair way into the river Parret; and Burnham Light, at east-south-east, is a good leading-mark along it. At low-water spring-tides, there is about six feet on the outer part of this channel; but farther in, there is only about three feet. The tide, however, rises rapidly here, and at one hour's flood a vessel will find a depth of twelve feet through it. At neap-tides the water does not ebb out so low, and about nine feet will then generally be found here at the lowest.

The *River Parret* forms only a tide-harbour, and always ebbs dry, excepting in the narrow runs where the stream works itself a channel of two or three feet deep, and excepting too in a few deep pools, hollowed out by the rapidity of the current.

The spring-tides rise full six fathoms (or 36 feet) in the entrance of the river, and about the Gore Sand, and four fathoms in Coombwich Reach. On spring-tides, therefore, and with a leading wind, vessels of very considerable burthen may proceed up the river Parret so high as Coombwich Reach, carrying twenty-four feet water over the sand-banks, and three or four feet more in the deep channels; and a vessel which does not draw more than fourteen feet, may always get up there on the springs, from whatever quarter the wind blows.

At neap-tides, there is not more than fourteen feet at high water on the sands in Coombwich Reach; so that a vessel drawing more than twelve feet ought not to attempt the river at such times, even with a fair wind. As a general rule it may be said, that whenever a vessel can find sufficient depth of water to carry her in along the Fair Channel, on the south side of the Gore Sand, towards Burnham Lighthouse, she will then, by the flowing of the tide as she advances, have water up to Coombwich Reach. As far as applies to the depth of the water, therefore, and with the exception of a few days on the neaps, there is no very material difficulty in the way of vessels proceeding up the river Parret to that point.

It must be readily perceived, however, that to a vessel descending the river, the difficulties of the navigation are much greater than to vessels ascending it. A vessel about leaving the river must start from Coombwich on the first of the ebb-tide, which falls very rapidly; so that if she happens to touch the ground, which is, perhaps, almost unavoidable at times in so narrow a channel, there is not the slightest chance of her getting off again, till the next flood-tide releases her.

If, moreover, the ebb-tide shall happen to be so far expended before she gets without the tail of the Gore Sand as to occasion her to ground on the hard flat which forms the bottom of the Fair Channel below Burnham, and if, whilst she lies aground there, it should set in to blow strong from the west or north-west, her situation would be extremely hazardous; and, in fact, serious losses have occurred here from this cause, limited as the resort of shipping is at present to the port of Bridgewater.

Coombwich Reach is about a mile in length, and of very sufficient width for vessels to pass and repass with facility. It is widest at the lower end, near the Ferry House; and here, too, the tide is somewhat less rapid than it is higher up. Here, moreover, a small stream of water called Coombwich Pill, having washed away for itself a deep channel out of the alluvial banks of the river, falls into the Parret. Into this Pill small vessels now enter, as a kind of dock, and there deliver and receive their cargoes, sheltered from the action of the tide. These circumstances seem to point out this part of Coombwich Reach as the most eligible spot for an entrance from the river into any lock or basin, if it shall be determined to bring the proposed canal, or any branch of it, to this part of the river Parret.

From Coombwich Reach up to *Bridgewater*, the Parret soon becomes so intricate and narrow as to be unfit for the purposes of navigation, excepting on a very limited scale. Opposite the town there is about sixteen feet at high-water spring-tides.

Proposed new Harbour at Stolford. A little to the westward of the small village of Stolford, or Storvord, and directly opposite to the tail of the Gore Sand, an extensive ledge of rocks, called the *Wick Rocks*, runs out to low-water mark.

This ledge is covered at about half-flood, and consists of firm ridges of lias rock of considerable elevation, and forms a shelter on the west and north-west, to a kind of bay or patch of soft mud, which spreads out within it to the extent of nearly a mile. The whole, however, ebbs dry at spring-tides, out to the extreme point of the Wick Rocks; but notwithstanding this circumstance, the place appears to me, after repeated examinations,

to afford all requisite facilities for an entrance to the proposed canal; and for the construction of substantial piers for the protection of shipping resorting thither.

A harbour formed here would be without all the dangers which beset the entrance to the river Parret, excepting only the Gore Sand, on the outer extremity of which a buoy must be placed. The flat of mud within the Wick Rocks is now used occasionally by small vessels, who there deliver and receive their cargoes of coal, kelp, &c. Vessels coming from the northward may always, at about half-tide, cross the tail of the Gore Sand, and, by doing so, would make a strait course into the entrance of the proposed harbour; and vessels from the westward would have no difficulty or danger of any kind to encounter in entering it.

If an artificial harbour of sufficient extent was constructed here, it would remedy the chief defect of Bridgewater Bay, which only wants a place of refuge for vessels to run to in stormy weather, to become a valuable roadstead. The entrance to this harbour would face the north-east, and be opposite to the Gore Sand, which would, in a great degree, protect it against the sea in north-east gales; in every other direction it would be sheltered by the range of coast, and by the piers which would be constructed on the Wick Rocks.

If it shall be determined to form a harbour at Stolford, it will, I think, be desirable to carry the piers out to low-water mark. Vessels drawing twelve or fourteen feet will then, on the springs, always be able to enter at an hour-and-a-half's flood, or even sooner; and during neap-tides, as the water does not ebb out so low by six feet, they would be able to enter at all times, excepting for about an hour at each period of low-water; and this will, I apprehend, be quite sufficient for general purposes.

The depths increase rather suddenly from low-water mark, just without the Wick Rocks; and from seven to nine feet will be found in a line between the entrance to the proposed harbour here, and the tail of the Gore Sand, at low-water spring-tides. On the neap-tides, from twelve to fifteen feet will be found on this line, at the lowest; and a little without it, and all over Bridgewater Bay, vessels will find good anchorage in from three to six and eight fathoms.

The deepest water along this coast is from Little Stoke, up past Benhole Point, to the Wick Rocks; these last forming the termination, as it were, of those masses of rocky cliffs, which, extending up from the westward, here meet and repel the flood-tide, as it is thrown over from the Nass Point on the opposite shore, and turn it in a north-easterly direction towards the Holmes. There seems to be no probability, therefore, of any accumulation of mud collecting here, to interfere with the navigation, or to impede the entrance to any artificial basin or harbour which may be constructed.

If a harbour was formed at Stolford, connecting with the proposed canal, it would afford great facilities to vessels proceeding to or from Bridgewater and the river Parret, as they may here enter and depart in safety at nearly all states of the tide. It would, however, I think, be advisable to have an entrance likewise at Coombwich Reach, so as to insure the greatest possible convenience for vessels of all sizes and denominations to enter and depart from the canal under every variety of circumstance.

The ground within the line of coast about Stolford is low and flat, and seems to be very suitable for the formation of basins and docks on the most extended scale; indeed, the natural advantages of this place, as regards the proposed object, are of the highest order, and leave little to be wished for beyond what may be supplied by artificial means. I certainly think that it will be advisable to form a floating dock here, into which vessels may be admitted by locks from the outer or tide-harbour.

The Holmes light, and the light at Burnham, will be excellent guides in approaching towards, or leaving, the proposed harbour; and with the addition of smaller lights on the pier heads, will enable vessels to enter or depart without pilots, nearly as well by night as in the day-time; which is an object of very considerable importance.

A secure harbour at Stolford will, as is before stated, remedy the great defect of Bridgewater Bay, and serve as a place of refuge into which vessels will run for shelter during the prevalence of westerly gales, and at all seasons when they cannot safely anchor out in the open bay.

If, however, a vessel shall, in running up the Bristol Channel with dirty blowing weather from the westward, get off the entrance to the proposed harbour about the time of low-water, or when there is not a sufficient depth for her to enter (to notify which, proper signals must be established), there would be sufficient sea-room for her to turn to windward until the tide had flowed to a sufficient depth; or if it shall blow very heavy, it might be advisable for her to run over to Penarth Roads, and anchor under the high land there, where vessels now seek for shelter in such circumstances, and wait there until it became more moderate.

If, moreover, it shall happen to blow a strong gale from the westward when a vessel is entering the British Channel, it may perhaps be expedient for her, as is now often done, to bring up in Blue Anchor Bay, under shelter of the high land of Minehead, and remain there until the gale abated, before she ventured to run up for the harbour; but in either of these cases, a vessel would be within a couple of hours' sail of the place; and Blue Anchor Bay to the west, and Penarth Roads to the north-east, may therefore be considered as most valuable appendages to the proposed harbour at Stolford.

Watchett. The whole of the south coast of the Bristol Channel, westward of Bridgewater Bay, is bold and safe to approach, and the tide ranges fairly along it; so that a vessel leaving any part of it will enter immediately into the open Channel. The shore recedes a little, so as to form a slight curvature between Little Stoke Point on the east, and the high land about Minehead on the west; and nearly in the centre of this line stands the town and pier of Watchett.

The present pier at Watchett is tolerably spacious. The water rises in it to about seventeen feet on the spring-tides, and at neap-tides vessels drawing eight feet may generally enter it at high water, if the weather is moderate. The tide ebbs out on the springs to a half, and sometimes to three quarters of a mile without the pier; and it does not rise, so as to flow up to the present pier-heads, until three hours' flood; nor is there

nine feet water within the pier till three quarters flood, or until the tide had flowed four hours and a half on the springs.

Watchett stands on nearly a strait line of coast; its roadstead is therefore perfectly open, and can afford shelter to shipping only when the wind is off the land; that is, from about south-east to south-west. The beach opposite to Watchett, and for several miles to the east of it, and as far to the westward as Blue Anchor Bay, is composed of firm ridges of lias rock, and of detached masses of the same material. This rocky beach extends down to about low-water mark, which seems indeed to define its boundary, as the bottom then gradually shelves away to two fathoms water, at about half a mile without it, mud and sand; and along this whole coast there is good clear anchoring ground in the offing.

When there is a fresh wind from the northward, and during the prevalence of our winter gales, a very heavy sea is thrown in over the rocky beach at Watchett; and it would be difficult to provide the requisite shelter here for vessels entering into the proposed canal at such seasons. I think a suitable entrance can only be formed by extending very substantial piers out to low-water mark, and from that point to deepen a channel or basin, into which the first lift of the tide may immediately flow, so as to enable vessels to enter and depart from it with as little intermission as possible.

Blue Anchor Bay is situated midway between Watchett and Minehead, about three miles distant from each, and to both places it serves as a roadstead. It is open on the east, but on the south and west sides it is completely sheltered by hills of considerable elevation, which approach towards the back of the bay, and continue up past Minehead, terminating at Greenelly point. It is sheltered from all winds from west-north-west, round to south and south-east; and even with the wind at north-east, which blows directly in, so good is the ground for holding, it being a stiff blue clay, that if a vessel is well provided with ground tackling, she may ride out a gale here in safety.

The shores of Blue Anchor Bay consist of loose shingle at high-water mark, and a little without it; beyond which, along the whole centre of the bay for a mile in width, there is a flat of mud on which vessels may lie aground in moderate weather. There is no danger or difficulty of any kind in entering this bay, or departing from it; and the general velocity of the tides in the Bristol Channel is here much lessened by the sudden turn of the coast to the northward.

If the proposed canal shall terminate at Blue Anchor Bay, it will, I think, be necessary to construct a very substantial pier or breakwater, extending out from the high rocky point at its eastern extremity, to shelter boats and small vessels from the north-east winds, and to protect the entrance locks; and this, in a nautical point of view, is all that appears requisite for rendering this a fit port of ingress and egress; but at whatever point on this coast the proposed canal shall terminate, whether here or elsewhere, it is quite certain that the existence of such a roadstead as Blue Anchor Bay, in the vicinity of the entrance, must be of great advantage to the vessels frequenting it.

II.

Under the second division of the subject, I am required to give my opinion at length, as to which of the several places examined and hereinbefore described would, in a nautical point of view, be on the whole the fittest termination for the proposed canal in the Bristol Channel.

Before giving my opinion on this point, however, I will first state what circumstances ought, in my judgment, to be kept chiefly in view in forming such an opinion.

1st. It must be borne in mind, that westerly winds prevail around the whole of our coasts for more than eight months out of the twelve. The wind has moreover always a tendency to follow the direction of the shore; so that when blowing up the Irish Channel at south-west and south-south-west, as it most commonly does, it will probably turn to the west-south-west and west, up the English and Bristol Channels. Looking, therefore, to the description of vessels which would use the canal, that is, vessels to and from Ireland, Wales, the western ports of England and Scotland, and the ports in the Bristol Channel, it appears desirable to have the northern termination as far to windward, or to the westward, as a suitable place of entrance can be found.

2d. The entrance to the proposed canal ought to be in a situation where vessels may be sheltered in stormy weather; and if such a sheltered anchorage cannot be found, so as to render it available for the purposes of the canal, it is essential that a place of refuge be formed at the entrance by artificial means, sufficiently spacious for the protection of vessels resorting thither; as, independent of the security to life and property which such a harbour would afford, every inducement to approach the entrance would lead to a more extensive use of the canal.

3d. It is highly desirable that the termination of the proposed canal shall open on a port or anchorage easy of access, where there are no material difficulties in the navigation, so as to render it necessary to employ pilots to conduct vessels into or out of it; for every expense of pilotage, and every delay arising from the difficulty of entrance, or other cause, will necessarily operate to deter vessels from approaching to and using the canal.

I will now apply the foregoing tests to the places described in this Report, taking them successively in the order in which they here stand.

Uphill Bay is far to the east, or to leeward, in the Bristol Channel; its anchorage is exposed; it is situated in an open part of the Channel, and no pilot would be required to enter it.

The River Parret.—Its navigation is so far difficult, that no vessel now goes up it without a pilot; the greatest difficulty, however, is in descending the river with a falling tide, there being no anchoring ground until the vessel gets without the Gore Sand; and the charge for pilotage on a vessel that does not belong to Bridgewater, from any part of the Bristol Channel into the Parret, and up as high as Black Rock or Coombwich Reach, is at present three guineas.

Proposed New Harbour at Stolford.—If a suitable harbour was to be constructed here, for vessels to run to for shelter in stormy weather, it would remedy the great deficiency of

Bridgewater Bay, and all this part of the coast. Its artificial piers would afford complete protection to vessels within it. It would be of easy and safe access, requiring no pilot to conduct vessels into or out of it. Without it, in Bridgewater Bay, there is good anchorage in moderate weather; and in strong westerly gales, there is excellent shelter for vessels both to the east and west of it, in Penarth Roads and Blue Anchor Bay. On the whole, if such an artificial harbour as I have contemplated shall be constructed here, I consider Stolford as a most eligible place for an entrance to the proposed canal.

Watchett is situated well to the westward in the Bristol Channel, but it is open to all winds, excepting those which blow off the land; and it would, I apprehend, be difficult to protect the entrance here in stormy weather.

Blue Anchor Bay is still more to the westward than Watchett, and is liable to few objections as an entrance to the proposed canal; it is easy of access, requiring no pilot to bring vessels into it; it is well sheltered from the westerly winds, and although it is open to north-east winds, the anchoring ground is so good in this bay that vessels may ride out a gale here in comparative safety; indeed, if the proposed canal shall terminate at either of the places before named, Blue Anchor Bay will be found to be of great advantage to the vessels using it.

Looking, then, to the whole subject, and founding my judgment on the foregoing facts and reasonings, I now give it as my opinion, that of the five several places hereinbefore described, two only, viz. Blue Anchor Bay and Stolford, possess, in a nautical point of view, such facilities for the formation of an entrance-harbour, and for the protection of shipping, as to justify me in recommending them as fit terminations for the proposed canal; at either of these places an eligible entrance may be formed; but of the two, I give the preference to Stolford.

If, however, such difficulties or impediments shall interfere, as to render it inexpedient or impracticable to bring the proposed canal either to Blue Anchor Bay or to Stolford; and if, in such case, it shall become necessary to select some one of the three other places herein described for a termination to the canal, the order of preference that I would assign to them for such purpose is as follows:

1st. The River Parret, at Coombwich Reach.
2d. Uphill Bay, if a double entrance can be formed there.
3d. Watchett.

Excepting the five places before described, I could not discover any spot on the south coast of the Bristol Channel, between Uphill Bay and Minehead, that would be at all suitable for the object in view.

III.

As the last object proposed under this head of inquiry, I have now to describe Beer Harbour, in the English Channel, and to give my opinion as to whether the works proposed to be constructed there will afford sufficient shelter to vessels using the canal.

Seaton Bay is formed by the lofty projecting point of Beer Head on the west, and Culver-hole Point on the east side. These points are about four miles apart, bearing nearly east-by-north and west-by-south from each other; and on the shore, about equidistant from each of them, stands the small town or village of Seaton. The bay is free from shoals or other hidden dangers; and over the whole space, both within and outside these points, there is excellent anchoring ground, the bottom being a stiff clay, in depths of from four to twelve fathoms, at low water. Seaton Bay forms the apex or centre of the great bay, included within the Start Point and Bill of Portland, the whole of which lies open to southerly winds, which throws in a heavy sea over this entire range of coast.

The little *Bay or Cove of Beer* is situated in the north-west angle of Seaton Bay, and is bounded on the north-east by White Cliff Point, and on the south-west by a bold lofty ridge of land, called Beer Head, or rather by a smaller projection in the shore within the head, called Hall Point. The space included between White Cliff Point and the Hall Point, which is known as Beer Bay, is of small extent, these points not being quite half a mile apart. It is, however, completely sheltered by the High Cliffs, which extend to and from Beer Head, from all westerly winds, as far to the southward as south-west or south-west-by-south; but from this quarter, all round to east-north-east, it is open and exposed.

To remedy this defect, and to form a harbour which shall afford shelter for shipping in east and south-easterly winds, it is proposed to construct a substantial pier or breakwater, running out into twenty-four feet water at low-water spring-tides, on a ledge of rocks which extend in a south-westerly direction from White Cliff Point as far out as the Hall Point. A part of this ledge ebbs dry at present, and yields some little protection to the fishing-boats and small craft belonging to Beer.

In addition to the pier on the eastern side, it will, I think, be highly desirable, as has also been proposed, to extend another pier from the Hall Cliff Point, to protect vessels in the harbour from the in-run of the sea and against the effect of southerly winds. These two piers will form a secure shelter for the harbour, in whatever direction the wind may blow. It will, moreover, I think, be right to form a basin of pretty considerable dimensions in the vicinity of the outer harbour, to serve as a kind of inner harbour, where vessels using the canal may conveniently lie, ready either to proceed along it to the northward, or to enter the English Channel.

Having twice very minutely examined all the localities of the proposed harbour at Beer, on one occasion during a gale of wind from west-south-west, and at the other time when it was blowing strong at south south-west; and having, moreover, carefully considered the effects which will be produced by the piers intended to be constructed there, both in easterly and westerly winds; I confidently declare my opinion, that vessels of three hundred tons burthen will not find any difficulty whatever in entering the harbour when it shall be completed according to the present plan, at any period of the tide and in any state of the weather.

The shelter which will be afforded by the high land of Beer Head to the proposed harbour, and to vessels approaching towards or leaving it, in westerly winds, is so effectual,

that if it blew a hurricane in the offing, a vessel will no sooner have gotten within the head than she will be instantly becalmed and may enter the harbour with perfect ease. When it blows strong at east or south-east, some precaution will of course be necessary in approaching the entrance, and care ought to be taken to make the vessel snug before she approaches to the pier heads; but when once she has hauled within them, she will be perfectly sheltered, and may ride out the heaviest gale in safety.

The Portland Lights are distinctly visible from the proposed harbour at Beer, and will be of great service as a guide to vessels departing from it at night. These lights, too, will serve to guide vessels in their approach to the harbour, and with the aid of smaller lights to be placed on the pier heads, will enable vessels to enter it at night, if the weather is moderate; and should it be stormy, the lights will be a good mark to point out to vessels their true situation when plying off and on in the bay, waiting for daylight to enter the harbour.

As an outlet from the ship canal, I consider the proposed harbour at Beer perfectly unexceptionable; and it possesses advantages in this respect which it would perhaps be in vain to look for elsewhere. All the objections which have ever been raised against it appear to hinge on the supposed prevalence of southerly winds, during which, it has been contended, vessels will find it difficult to work out of Seaton Bay, and the great bay without it. The fact however is, that the wind rarely blows home across the English or Bristol Channels, either from the northward or the southward, and scarcely ever for any long continuance; but rather, as has been before stated, it assumes the direction of the coast; if, however, it shall happen to blow so strong at south or south-east that a vessel cannot get out of the harbour, I am quite sure that she will be in a better situation there, until it moderates, than outside in the channel.

I think that the proposed harbour at Beer, when it shall be completed according to the present plan, will become a place of considerable resort as an asylum harbour for coasters and other vessels navigating the English Channel. Such a harbour is much wanted, as at present there is no place of shelter along the whole coast from Portland to the Start; and vessels embayed between these points in strong south-easterly gales are exposed to hazard, more especially in the long winter nights, having no port to leeward for which they can run. With this view, then, generally, as well as for the uses of the ship canal, the vessels frequenting which will necessarily require a considerable space for their accommodation, I strongly recommend that the proposed harbour at Beer be made as large as the nature of the situation will admit of, and that all practicable facilities be provided there, to expedite the entrance and departure of shipping.

I ought, perhaps, here to add, what I sincerely think, that the plan of taking the canal at once on to Beer Harbour, is, in my opinion, infinitely preferable to that which was laid down when this subject was under discussion some years ago; for if the entrance harbour could have been formed, where it was then proposed to construct it, in Seaton Bay, and if it could have been kept free from shingle, vessels could not have entered into it, excepting in moderate weather; and the difficulty and delay in transporting them thither from Beer Harbour would have been so considerable as to deter vessels from using either the one or

the other to the extent that the promoters of the canal had a right to expect, from the large sums of money which would have been expended in the formation of these two harbours.

Among the natural advantages of Beer Harbour may be reckoned a plentiful spring of water, which issues out from under White Cliff Point. This might be conducted along the eastern pier, and would serve to supply any number of vessels with water, in the shortest time, and the most convenient manner possible. During war, the facility of procuring a supply of water in such a situation would be an important accommodation to our fleets and cruizers; and as the water is peculiarly pure and keeps remarkably well at sea, the procuring a supply of it here would probably conduce to the health of the crews, as well as to a saving of time and expense.

The harbour at Beer will, I think, in its character and consequences, be very similar to the proposed harbour at Stolford; it will in short be the same to the great bay between Portland and the Start that the latter will be to Bridgewater Bay and the Bristol Channel: each of them will serve as ports of refuge for vessels in stormy weather, and both of these places will, in my opinion, be fit terminations for the proposed canal.

London, 3d December 1824. *Geo. Nicholls.*

English and Bristol Channels Ship Canal.

Having concluded my Report on the nautical part of the subject referred to me, I now proceed to consider the second head of inquiry, in which I am directed 'To endeavour to form an estimate of the advantages which the proposed canal is likely to afford; and whether, in my opinion as a seaman, and with reference to general commercial purposes, these advantages will be such as to justify the expense to be incurred in its formation;' on this subject, I now, for the information of the committee of subscribers to the proposed canal, beg to make the following Report:

The questions here referred to me are of an extensive nature, and necessarily embrace details and inquiries of great interest and importance. There are, however, certain facts to be obtained on which the answers of these questions mainly hinge; these facts I will endeavour plainly to state; and afterwards will deduce such inferences from them as shall, I venture to hope, when taken collectively, afford a satisfactory answer to the inquiries proposed.

It will, I think, prevent confusion, and conduce to a right understanding of the subject, if I class the several objects of inquiry under distinct heads, as follows:—

I. The probable saving of time and expense, by means of the proposed canal.

II. The risk which will be avoided.

III. The extent to which the canal is likely to be used, when completed; and the probable revenue then to be derived from it.

I.

Under the first head of inquiry, the most obvious fact to be noticed is the great saving in distance which vessels passing from the Irish and Bristol Channels into the English Channel, and *vice versâ*, will effect by using the proposed canal, instead of going round the Land's End; and which saving cannot be reckoned at less than three hundred miles. This, under common circumstances, may, I apprehend, be considered as a saving of six days; for a direct advance on their voyage of fifty miles per day will be found to be beyond the average rate of sailing of coasting vessels.

In the different nautical directions for navigating the English and Bristol Channels, it is stated by some, that westerly winds prevail for eight months; in others, that they prevail for nine months in the year; the truth I believe lies between them. To vessels, therefore, proceeding round the Land's End into the Irish or Bristol Channels, or from these Channels to London, and the other ports in the English Channel or German Ocean, there are about nine chances out of twelve that they will meet with contrary winds during one-half of their voyage.

Looking, then, to this last circumstance, as well as to the saving in distance, I am quite sure that vessels navigating between the above-named points will on an average throughout the year, save a week's sail in each passage out and home, by using the canal instead of going round the Land's End, reckoning that the passage of a vessel through it will occupy about a day and a half; for, the width of the canal being ninety-five feet, vessels will be able to pass each other with facility; and as it has on the whole a level range of thirty-four miles for navigation, uninterrupted by locks, and as moreover the direction of the canal will be nearly north and south, whenever the wind shall blow from the eastward or from the westward, as it most generally will do, vessels will be able to use their sails with advantage in passing through it, and I see no objection to their being permitted to do so, under proper regulations. Sloops and fore-and-aft-rigged vessels will mostly be able to sail through; at times, recourse must be had to tracking, either by the crews or with horses, or occasionally by both; or it may very possibly hereafter be found expedient to establish some kind of steam-boats on the canal, for the purpose of towing vessels through it.

There are, however, other circumstances connected with the passage of vessels round the Land's End from the ports on the south coast of Wales, which must, as far as the Welsh trade is concerned, greatly increase the above estimated saving of time; these circumstances I will here state.

The regular traders between Cardiff and London generally make six complete voyages in the year. The passage from one place to the other sometimes occupies thirty days, it has been done in six; but these are alike unusual occurrences. From Swansea and Milford, the passage is somewhat less; from Newport and Bristol it is rather more; perhaps twelve days may be taken as about the average length of passage each way between these places and London; but then the voyage must only be considered as

commenced, when the vessel has actually sailed from and cleared the last port in the British Channel; for, excepting in the summer months and in very moderate weather, vessels cannot depart from the ports in South Wales to go round the Land's End, unless the wind be in such a direction as will enable them to sail out clear of the coast in one tide; if they cannot accomplish this, the returning tide, which is here exceedingly rapid, would drift them back again, probably to leeward of the port whence they started. In summer, vessels do occasionally venture to sail with a westerly wind, and take the chance of anchoring to save a tide; but in winter never.

The most usual place of rendezvous for vessels waiting for a wind to sail from the Bristol Channel is Penarth Roads, near to the entrance of Cardiff River, where they may lie sheltered under the high land of Penarth, and whence they can readily proceed on their voyage, in case the wind should become favourable for their doing so. The detention here is often for a considerable length of time; and it was only last year that a great number of vessels were actually kept here, and at Swansea and Milford, for thirteen weeks, by the continued prevalence of westerly winds.

The delay occasioned to the Welsh trade by this last-mentioned cause alone, cannot, I think, on an average of seasons, be reckoned at so little as a week for each voyage, or six weeks in the year; and if the ship canal was cut from Stolford, or some convenient point in the Bristol Channel, across to the proposed termination at Beer Harbour, in the English Channel, no such delay would take place; for vessels from all parts of Wales might then cross over to its entrance, from whatever point the wind blew, and in thirty-six hours be transported to an open part of the English Channel, either in winter or summer.

On the whole, then, and taking into account this last cause of detention (which, although it is not exclusively confined to, yet applies more especially to vessels frequenting the Bristol Channel), as well as the other sources of delay before noticed, and regarding moreover the facilities which the proposed canal will yield generally to the communications between Ireland and the western parts of England, and all the ports on the English Channel and German Ocean, I think that I do not over-rate its advantages when I reckon, that, on an average of circumstances and seasons, a fortnight will be saved by all the vessels which shall regularly use it in each of their outward and homeward passages, instead of going round the Land's End; or, in other words, that where six entire voyages are now performed in the year, vessels from the Welsh ports will then always, and other vessels will generally, be enabled to make twelve.

The saving in expense will, of course, bear a certain proportion to the saving of time; and we may arrive at some kind of approximation to its amount by attending to the following statements :—

In the returns made to Parliament during the last session, on the motion of Sir Thomas Lethbridge, Bart., it appears that five thousand and eighty-eight vessels [*see* Appendix, p. 620], whose registered tonnage amounted to four hundred and tenthous and six hundred and seventy-three tons, passed round the Land's End, from one part of the British coast

to another, during the year 1823. The average size of these vessels, as per register, was eighty tons and three quarters, and probably, therefore, each of them would carry about one hundred tons of cargo.

I will suppose each vessel to be navigated by a master and five other persons, men and boys, and I will take the charge for wear and tear of the vessel, and the expense of wages and maintenance of the crew, at only £.2 per diem on an average; this, for the five thousand and eighty-eight vessels, will be £.10,176 per diem, or £.142,464 for a fortnight, which is above calculated to be the probable saving of time by means of the proposed canal, to all vessels using it, instead of going round the Land's End. I will, however, omit the other branches of trade, and for the present confine my observations to the above number of vessels alone; it being sufficient for my purpose to show what the saving will be here, and from which its probable amount on the total number of vessels passing round the Land's End may be easily inferred.

From the above estimated saving of £.142,464, however, must be deducted £.75,290. 1*s*., which sum would be paid on the amount of tonnage passing along the canal, at 1*d*. per ton per mile, for forty-four miles (I have here taken the registered tonnage), leaving the great saving of £.67,173. 19*s*. to the shippers of goods and owners of vessels in wear and tear, and the wages and maintenance of the crews; and when to this is added, as there ought to be added, a fortnight's interest on the value or cost of the cargoes of these five thousand and eighty-eight vessels, and the risk or cost of insurance which will be saved by means of the canal, the amount of saving, as above estimated, will be greatly increased.

Having, in the preceding estimate, purposely excluded foreign vessels, and British vessels trading to foreign ports, and likewise those passing the Land's End to and from Ireland, I ought perhaps to state, that the number of all these is very considerable, as will be seen by reference to the Appendix (p. 621.) I have intentionally abstained from noticing the expense of tracking or towing vessels along the canal, as this will, I apprehend, be nearly covered by the sums which are now paid to the several lights on the coasts.

Another consideration as to the saving of expense is, that vessels returning round the Land's End, after having discharged their cargoes, are now obliged to take on board a great quantity of ballast, to enable them to carry a press of sail, in case the wind should set in strong from the westward; else they would not be able to weather the land. This occasions expense and delay, both in receiving and discharging their ballast, as the immense accumulations of it at Newport and the other ports in South Wales sufficiently testify. If light vessels had an opportunity of passing through the canal, and thus avoiding the dangers of a stormy point of the coast, they would then take on board very little ballast in their return voyage.

II.

The second head of inquiry refers to the avoiding of risk by means of the proposed canal.

Of the dangers attendant on the navigation round the promontories of Cornwall at all seasons, but more especially during the winter months, a great deal might here be said;

the frequent occurrence of shipwreck on this coast, and the loss of life by which it is accompanied, being matter of public notoriety. I well remember the impression made on my own mind, many years ago, whilst traversing the shore adjacent to and between the Land's End and the Lizard, where the numerous graves of seafaring persons who had perished on these inclement coasts, and whose bodies were interred near the spot where they had been washed on shore, frequently in clusters of many together, were calculated to awaken the most painful sensations.

Note.—At one place alone, near Gunwalloe, there have been between thirty and forty of these unfortunate creatures buried; the marks of their graves are still to be seen.

The proposed canal, when completed, will assuredly tend to lessen the number of shipwrecks; and by so doing will lessen, if it does not annihilate, the system of "wrecking," with all its demoralizing effects on the character and habits of the people, which has so long disgracefully prevailed on the coasts of Cornwall; indeed, the undertaking is well deserving of public support, on grounds quite distinct from any calculation of advantage in a pecuniary point of view—I mean, from motives of humanity and general benevolence; for I know of no public object that combines so many of those considerations, which must ever influence the patriot and the philanthropist, or that would conduce to a greater saving of human life, or be productive of more extensive benefits to the country and to individuals.

Wishing to place this interesting subject in its true light, and to found it on something like official returns, I have had the books at Lloyd's carefully examined, and statements abstracted therefrom, of, 1st, the number of vessels which have been driven on shore or wrecked on the coasts of Devon, Dorset, Somerset and Cornwall, between the two points of termination of the proposed canal, or the vicinity of them; and 2dly, the number of vessels which have been dismasted, or sustained other injury at sea, either off this line of coast, or in their approach towards it. [*See* Appendix, p. 621.]

By these statements it will be seen, that on an average of the last nine years, upwards of forty-two vessels annually have been either totally lost, or else have sustained damage, in consequence of being driven on shore within the above limits; and also, that within the same period, sixty-two vessels per annum have met with injury at sea in the vicinity of these coasts, or in their approach towards them. If the sacrifice of human life and the destruction of property which ensued, could have been added to these statements, it would have exhibited the whole subject at one view; but it was found impracticable to do this.

The numbers inserted in the statement above referred to [*see* Appendix, p. 621], are considerably within the actual amount of injury sustained, as the majority of small coasting vessels, being those mostly exposed to the casualty of shipwreck, are neither insured nor noticed on the books at Lloyd's. The statement, however, although so far incorrect, will probably be deemed sufficient for the present purpose. If any addition shall be thought necessary for giving to it a greater effect, such addition may be found in nearly the last page of the extracts which I have procured from the lists at Lloyd's, where,

in that of the 7th of November 1823 (just twelve months ago) it is stated, that "the whole coast, from St. Ives to the Land's End, is strewed with wreck, and it is impossible to ascertain the names of all the vessels that have suffered, as most of the crews are drowned."

That Government will give its decided support to the undertaking, it is impossible to doubt; for, independent of all its other advantages, and the facilities which it will afford in the conveyance of timber from the Forest of Dean, and the country connecting with the Bristol Channel, and for the transit of stores between the naval depôts of Milford, Portsmouth and Plymouth, if a war should break out, vessels, by going through the proposed canal, would be saved from passing along nearly one-half the line of coast, and that, too, the part most exposed to the depredations of privateers and cruisers; and, in all probability, millions of our resources would thereby be saved to the country, and kept from augmenting the power of the enemy.

III.

The last division of the subject embraces considerations as to the extent to which the canal is likely to be used when completed; and the probable amount of revenue then to be derived from it.

The first consideration under this head is as to the sufficiency of the proposed depth of fifteen feet water for the accommodation of all such vessels as shall be likely to use the canal; and this question may be most satisfactorily settled by reference to official documents. In the returns laid before Parliament last session [*see* Appendix, p. 621], it appears that the eight thousand four hundred and sixty-five British vessels which passed round the Land's End in 1823 averaged in size ninety-one tons each; and the one thousand seven hundred and seventy-seven foreign vessels which passed round the Land's End during the same period averaged one hundred and forty-seven tons each. Now the draught of water of vessels of different sizes and descriptions, as given in evidence before a Select Committee of the House of Commons in 1800, by the principal ship-builders in the river Thames [*see* Appendix, p. 622], shows that vessels of two hundred tons burthen draw, when laden, from twelve to thirteen feet water, and from seven to eight feet when empty.

It appears, therefore, that the proposed depth of fifteen feet is sufficient for vessels of upwards of two hundred tons burthen, whilst the average size of vessels which passed round the Land's End last year is not quite one hundred tons; and consequently, that the canal, as now proposed, is fully equal to the accommodation of the trade likely to pass through it.

When the canal shall be rendered perfect and complete in all respects, the extent to which it will be used must, in some degree, depend on the rates per ton which it may then be determined to charge on goods and vessels passing through it; but as there is little danger that the public will be deterred from using this canal by the imposition of a high rate of tonnage, we may venture to consider this subject, which is of such vast importance to the promoters of this undertaking, under its natural bearings.

In the Prospectus published by the Committee of Subscribers in August last, upon which I therefore calculate, it is assumed, that the expense of maintaining the canal, including wear and tear and management, will amount to £.1,000 per mile, or £.42,000 per annum. Supposing the works to be completed in a proper manner, and that all things needful were provided at the outset, I do not see how so large an expenditure can be afterwards required; and I consider that an allowance of £.500 per mile, or £.22,000 annually, will be abundantly sufficient to provide for all repairs, the expense of management, and every other contingency. Be the expense what it may, however, it is important to show that the revenue which will probably be derived from the internal traffic on the canal will, as has been estimated by the Committee, be adequate to meet it, without trenching on the other sources of income hereafter to be enumerated.

This must, of course, be in some measure suppositious; but I think that there will be a great internal traffic on the canal, almost immediately after its completion. I think, moreover, that this traffic will progressively increase, as the interior communications with the canal, by means of collateral branches and tram-roads, shall be perfected, so as to become eventually a very productive source of revenue to the proprietors.* I have formed this opinion after a very laborious inquiry, and I will now specify some of the data on which it is founded.

There are extensive lime-quarries at various points along the proposed line, at which there is at present a large consumption of culm. These will no doubt increase in number and extent, when the canal shall be brought into operation; and the tonnage from lime and culm may therefore be expected to be considerable. Large quantities of pottery, bricks and tiles, are now made in the vicinity of the proposed line, where the materials abound, and are distributed by land-carriage to various distances. I am given to understand that potters' clay, and materials for brick-making, &c., will be raised in large quantities in progress of the work. The value of all these to the country, and as a source of revenue, will be greatly increased so soon as coal and culm can be conveyed along the canal to the places where the materials are found; and a large export of their produce may be expected, as well as their diffusion over a wider surface of country. That beautiful substance, the beer-stone, which is so suitable for in-door and ornamental work, will be distributed by the canal through the country; it will too, no doubt, so soon as a harbour shall be provided into which vessels may safely enter to receive it on board, be conveyed to London and other parts of the kingdom. There will also be an export both to the English and Bristol Channels, as well as a transit from one point of the interior to another, of all kinds of grain, wool, cider, cheese, potatoes in large quantities, hay, timber for building and agricultural purposes, flint, lime, chalk and other manures, and road-stone to a great extent; and it is from these and other sources that I confidently look for a revenue, to cover the expense of maintaining and managing the canal.

I will now endeavour to show what quantity of tonnage may be expected to pass along the canal, and the amount of revenue which the proprietors may reasonably calculate on

deriving therefrom. In doing this, it is my wish to avoid hypothesis, as far as the nature of the subject admits of it; and I will throw out of the calculation all cases of doubtful import, or where the probabilities shall seem to approach to an equality. I will, in short, strive to be as guarded as possible, my sole desire being to elicit the truth, and to exhibit this important subject in its proper point of view. For the conveniency of reference, I will number the several heads as I proceed in discussing them; and afterwards I will condense the whole into one short statement.

I.—I consider that the whole line of country, from five miles south of Taunton and Langport to the shores of the English Channel, and for a very considerable distance on each side of the canal, will eventually, if not immediately, derive from it their supplies of coals, timber, groceries, dry goods, and all other articles of import. This comprises an extensive and populous district, including the large and opulent towns of Honiton, Ilminster, Axminster, Chard, Crewkerne, besides several considerable villages. The entire population of this district cannot, I imagine, be less than 90,000, which, reckoning that each person consumes a ton of coals per annum on an average, (and this, including the consumption of manufactories and gas-works, is a low average,) will require 90,000 tons; but as the coals for the supply of the country bordering on the canal will not be carried along its entire length, and as I wish rather to keep within than to exceed the reality, I will take the quantity of coals for the whole line at only one-half, or 45,000 tons. The quantity of groceries and other goods for the supply of the same district may be safely taken at 15,000 tons more, making a total of - - - - - - - - Tons 60,000

II.—I consider that the whole of the south coast of England, and the country within it, will eventually be supplied with coals from the Welsh ports by means of the canal, as it will be from thence that the best article for general use may be procured, and at the cheapest rate. The quantity of coals consumed along the southern shores of the kingdom has been variously estimated at from 1,400,000 to 2,000,000 of tons; I will take it 1,000,000 of tons only, and I will suppose that of this quantity no more than one-half will pass through the canal, or - - - - - - - - - - - - - Tons 500,000

III.—Blue lias-stone for paving, and for the roads, and which also burns into lime of the very best quality, exists in the greatest abundance along the northern part of the proposed line of canal; and at the point where it will join the Bristol Channel, the shore for many miles is covered with an almost inexhaustible accumulation of blue pebbles, similar in quality to the Aberthaw lime-stone, which is deservedly held in such high estimation all over the kingdom. That these valuable materials will be carried along the canal, and distributed over the southern parts of England, cannot be doubted, and I am confident that I shall be very far within the amount in reckoning the annual tonnage from this source at only - - - - - - - - - - Tons 30,000

IV.—It appears by the Parliamentary Returns, an abstract of which will be found in the Appendix (p. 620), that 5,088 vessels passed round the Land's End last year, between the western. and the southern and eastern ports of England; nearly all of these would, I am persuaded, have passed through the canal had it then been formed; and we may calculate on the whole of them doing so hereafter. The amount of their registered tonnage was 410,673 tons, but I will suppose that only one-half this quantity will pass through the canal, or - - - - - - - - - - - - Tons 205,337

V.—It moreover appears in Appendix, p. 621, that 685 + 608 = 1,293 foreign vessels passed round the Land's End last year, to and from foreign ports and the western ports of England, whose cargoes amounted to 191,801 tons. Now all the motives which can be influential with our own coasters to avoid the Land's End and to go through the proposed canal, must operate still more powerfully with foreigners, who are comparatively ignorant of our coasts, and who entertain the greatest dread of them. I believe, therefore, that the whole of these foreign vessels would have used the canal; but I will only reckon here on two-thirds the amount of their tonnage passing through it, or - Tons 127,868

VI.—It also appears in Appendix, p. 621, that 746 + 725 = 1,471 British vessels, engaged in trading between foreign ports and the western ports of England, passed round the Land's End last year; their registered tonnage amounted to 178,020 tons, and I will suppose that only one-half of this quantity will pass through the canal, or - - - - - - - - - - - Tons 89,010

VII.—It appears, lastly, in Appendix, p. 621, that during the last year, 93 + 291 + 219 + 265 = 868 vessels, with 106,663 tons of cargo, passed between Ireland and foreign ports; and also, that 1,522 vessels, registered at 143,273 tons, passed between Ireland and the southern and eastern coasts of England, making a total of 2,390 vessels, British and foreign, with 249,936 tons of cargo, which passed round the Land's End to and from Ireland. What proportion of this would have passed through the canal, had the option of doing so existed, I have not sufficient information to enable me to estimate with accuracy, not having visited any of the ports of Ireland for the purpose of obtaining it; but as a considerable number of these vessels were foreigners, it will, perhaps, not be thought too much if I reckon on one-third of their tonnage, or - - Tons 83,312

Under none of the above heads have I stated the quantity of English timber for ship-building and other purposes, which will pass through the canal from Wales, the Forest of Dean, and the country bordering on the Wye and Severn, although this quantity will be very great; as, independently of the consumption in private yards, the King's yards at Devonport, Portsmouth, Chatham, Woolwich and Deptford, derive a considerable part of their supplies of timber from this quarter; but as part of this timber is now sent round the Land's End, and the vessels employed in carrying it are included in the Parliamentary Returns herein referred to, I have abstained from founding any estimate of

revenue thereon. For the same reason I omit noticing the quantities of iron, copper, tin plates, pipe-clay, foreign timber, &c. &c., all which, as now sent, are included in the returns to Parliament. It may be remarked, however, that the greater facility of transit which will be acquired by means of the canal, will tend to increase the demand for, and consequently the production of, these articles, in common with all others within the sphere of its operations.

Having above classed, under separate heads (Nos. I. to VII.) the quantities of tonnage which may be expected to pass through the canal, and become available as a source of revenue to the proprietors; the next consideration is, what rate per ton ought to be charged thereon? The committee of subscribers, in their prospectus, have assumed an average rate of 1 *d.* per ton per mile on all goods conveyed along the canal; this charge appears to be moderate and unexceptionable on the part of the public, and it must now be shown that it will afford a sufficient remuneration to the proprietors.

I will here bring together the several amounts of tonnage as they have been above estimated, each under its distinct head:

	Tons.
Under the 1st head - - - - - - - - -	60,000
„ 2d „ - - - - - - - - -	500,000
„ 3d „ - - - - - - - - -	30,000
„ 4th „ - - - - - - - - -	205,337
„ 5th „ - - - - - - - - -	127,868
„ 6th „ - - - - - - - - -	89,010
„ 7th „ - - - - - - - - -	83,312
Total number of Tons estimated to pass through the canal annually - - - - -	1,095,527

	£.	s.	d.
At 1 *d.* per ton per mile, the above estimated number of tons will amount to £. 4,564. 13 *s.* 11 *d.* chargeable for every mile of transit; and as the canal will be 44 miles in length, as measured on the new line, this will produce a clear annual revenue of - - - - - - -	200,846	12	4
To this must be added a tonnage-rate to be levied on all vessels taking refuge in, or using the proposed harbours at Beer or at Stolford; and also, on vessels proceeding along the canal to Bridgewater and the river Parret; the amount annually from these sources will, I think, on an average of years, be at least - - - - - - -	10,000	–	–
Clear income arising from the canal, and applicable to a dividend among the proprietors - - £.	210,846	12	4

The probable amount of revenue here stated is certainly large, but as every source from whence it is estimated to arise has been distinctly exhibited, the whole is open to scrutiny and invites inquiry; large however as this estimated revenue may be considered at present,

I yet think that it will, at no very distant period, probably within a few years after the completion of the canal, receive a considerable augmentation, even if peace shall so long continue; but should the country be involved in a war, and the risk from an enemy's cruizers be added to the present dangers of our coasts, there can be no doubt but that the effect would be greatly to increase the traffic on the canal. Independently of this last consideration, however, I have reason to think that there will be a progressive increase in the trade on the canal after it shall be completed; and this opinion I found, chiefly, on the manifest improvements which are almost daily taking place in the several ports in South Wales, and the rapid extension of the trade along the Severn and its communications.

As this part of the subject is of more than ordinary importance to the promoters of the present undertaking, it will not perhaps be thought out of place here to insert a short notice of the principal ports in the Bristol Channel; deeply interested as all these must be in the proposed canal, which will so greatly conduce to the security of their commerce, and which will again in return be itself benefited by their prosperity. I do not pretend to minute accuracy in what I am about to state, but the quantities will be sufficiently near the truth, for all the purposes of general reasoning on this occasion.

Swansea is become a place of very considerable importance. Its staple is the copper trade; but the commercial relations between London and the ports of Neath and Swansea are rapidly increasing. In the year 1821 there were three thousand eight hundred vessels cleared out from Swansea and Neath, and about four hundred and fifty thousand tons of coals, culm and stone-coal, besides copper, iron, tin-plates, and other articles, were exported to London and the ports of Great Britain and Ireland. Since that time the export of coal has materially increased, particularly from the vale of Neath, in which there is one of the largest and most productive coal-beds in the kingdom, and which, as yet, has scarcely been opened; but now that a canal communication is formed between it and the harbour of Swansea, an inexhaustible supply, both of bituminous and stone coal, is here laid open to the country at large. Swansea imports, chiefly from London, large quantities of timber, groceries and other dry goods, for the supply of its back country.

The ports of Carmarthen, Llanelly and Milford are all rapidly increasing in importance, and swell the aggregate of prosperity, which is to be witnessed along the whole of the Welsh coast.

Cardiff exports annually, besides coals and about three thousand tons of tin-plate, not less than sixty thousand tons of iron, of which full thirty thousand tons go to London, and the ports on the German Ocean and English Channel. There is also a foreign trade here, forty French, Dutch and Prussian vessels having been at this port in one year. About 4,000 tons of timber, and a similar quantity of groceries and dry goods, are annually imported for the supply of the interior. Vessels drawing fourteen feet of water can now be admitted into the floating-dock here, but the size of this is much too confined for the trade of the port.

Newport (Glamorganshire) is a rapidly-increasing place; it has a fine river, and is only deficient in a roadstead; if floating-docks were constructed here, as they easily might be, and I have no doubt will be, Newport would speedily become a place of first-rate importance. Besides other articles, there are now five hundred thousand tons of coals, and about ninety thousand tons of iron, exported from it annually; of the last, about twenty thousand tons are sent round the Land's End to London and other ports. Large quantities of tin-plates are also sent from hence, of which one thousand five hundred tons go to London. The trade of Newport, for supplying the back country, is considerable, from eight thousand to ten thousand tons of timber and dry goods annually; and about twenty foreign vessels come here in the course of the year.

The port of Chepstow is confined to the timber trade, foreign and domestic. Sea vessels bring foreign timber here, and discharge it into trows and smaller craft, to be taken up the rivers Wye and Severn; and these rivers afford great facility for bringing down bark and oak timber for ship-building. A considerable number of vessels are built here.

The importance of Bristol, in a commercial point of view, is so well known, that I need say but little respecting it here; excepting, that as a great proportion of its intercourse with the ports on the south and east coasts of England, and with France, Holland and the Baltic, will be carried on through the proposed canal, instead of going by the circuitous and dangerous route round the Land's End, every support to the undertaking may be reasonably expected from the merchants, ship-owners and capitalists of Bristol.

Gloucester has hitherto hardly been known as a port; but as the Gloucester and Berkeley Canal will be completed and opened next year, vessels of three hundred and four hundred tons burthen will then be able to pass along it to the wharfs at Gloucester, which will thus be converted into a port for the reception of sea vessels into the heart of the country. As the inland communications of this place, by means of the river Severn, and the canals which connect with it, are very extensive, it will probably become, ere long, a place of considerable importance; it seems, indeed, the natural port of Worcester, Birmingham, Coventry, and an extensive manufacturing district; and as its intercourse with the ports on the south and the east coasts of England, and with those in the north of Europe, will necessarily be through the proposed canal, the increase of the trade of Gloucester must prove advantageous to this undertaking.

Looking, indeed, to the several ports in the Bristol Channel generally, and to the country communicating with it, it is so evident that the whole must be benefited by the proposed canal, that I cannot doubt of its receiving the most decided support from this quarter.

Rich as the south of Wales is in natural productions, its chief want is a convenient market for its produce; and this canal will bring it at least three hundred miles, or a fortnight's sail, nearer to such market, as well as cut off the only part of the voyage for the transit of its commodities, which is really dangerous. The iron-masters, the proprietors of collieries, and the great shippers and capitalists of South Wales, must be fully

sensible of this; and they will therefore, it is to be presumed, support with all their influence an undertaking that will hereafter become so identified with, as well as conducive to, their commercial prosperity.

The merchants and importers of London are perhaps nearly as much interested as any others in promoting this canal; for, as the freights on goods from Wales, Ireland, and the north-western ports of England, are for the most part paid by them, and as the delays and difficulties of the present passage round the Land's End necessarily increase the cost of freight, as well as the expense of insurance, it follows, that if these delays and dangers could be lessened, as it has been shewn that they will be lessened by means of the proposed canal, the expenses to the London importer will necessarily be lessened likewise.

The landed interest, too, of Devon, Somerset and Dorsetshire, and generally of the whole interior of the western counties, will be greatly benefited by this canal. It will give them a vent for their produce, and procure a supply of all the imports which they may stand in need of, from the first hand and at the cheapest rate; added to which, it will cause a circulation of much capital in their country.

But of all the interests which are likely to be benefited by this undertaking, perhaps there are none that will derive such immediate and extensive advantages as the collieries in Wales. The consumption of coals by steam-engines, and in our gas-works and manufactories, is every day increasing. The canal will open the midland country of Devon and Somerset, and will yield the colliers a safe and expeditious access to the whole of the south coast of the kingdom, and even to London itself. The stone-coal too, which is so abundant in South Wales, and the consumption of which is so rapidly increasing, will most probably be brought into very extensive use so soon as the canal shall be opened. This coal is hard, and burns a long time, emitting great heat, with but little smoke; it is therefore peculiarly well fitted for the numerous breweries, drying-houses and manufactories in and around London, where the annoyance from the smoke which is at present emitted from such places is so loudly complained of.

In the observations immediately preceding, it will be seen that I have confined myself to the trade of the Bristol Channel, present and prospective. The commercial intercourse between this country and Ireland, however, ought not to be overlooked. The Irish trade generally is, I believe, very rapidly increasing; we may expect that it will continue to increase, and its prosperity will increase the revenue of the canal; as vessels bound to London from the north-east coast of Ireland, perhaps from all the ports to the north of Waterford, would, I apprehend, very generally pass through it. The same may be said of vessels from Glasgow, Whitehaven, Lancaster, Preston, Liverpool, and other ports on the north-west coast of England; but I do not consider myself qualified to speak decisively, either with regard to the Irish trade, or that of the ports last named, not having made the requisite inquiries on the spot, nor procured that kind of information which I consider necessary for enabling me to form a sound opinion thereon.

I trust, however, that enough has been said to afford answers on the three subjects of inquiry proposed at the commencement of this Report; and that it has been satisfactorily shown that the canal, when it shall be completed, will—

1st. Occasion a great saving of time and expense to the vessels using it, instead of going round the Land's End:—(*See* pages 608–610.)

2d. That it will be the means of avoiding risk, and saving much property, and preserving many valuable lives:—(*See* pages 610–612.)

3d. That it will probably be used to such an extent as to yield a revenue to the promoters of it, adequate to the expense which will be incurred in its formation:—(*See* pages 612–613.)

If it shall be thought that I have entered too minutely into the details which form the ground-work of this Report, I can only say in extenuation, that my doing so has been occasioned by my desire to show, beyond the possibility of doubt, that it will be decidedly for the advantage of a very large portion of the community to promote the formation of the proposed canal, and to support it when completed; it appearing to me absolutely necessary to do this, before the public were invited to come forward in aid of an undertaking of such magnitude and importance as the proposed English and Bristol Channels Ship Canal.

London, December 3d, 1824. *Geo. Nicholls.*

APPENDIX referred to in pages 609–615.

A STATEMENT, abstracted from the Returns to Parliament, of the NUMBER of VESSELS, and the AMOUNT of TONNAGE, which passed round the *Land's End* during the Year 1823, between the West and South-east Coasts of *England.*

	Vessels.	Tons.
From the West Coast of England to the South and East Coasts - - - - -	2,833	236,876
From the South and East Coasts of England to the West Coast - - - - -	2,255	173,797
TOTAL - -	5,088	410,673
	Average size of Vessels, 80¾ tons each.	

APPENDIX referred to in page 610.

AN ABSTRACT of all the VESSELS that passed round the *Land's End* in the Year 1823, from Returns laid before Parliament in the last Session.

	BRITISH.		FOREIGN.	
	Vessels.	Tons.	Vessels.	Tons.
From the West Coast of England to the South and East Coasts	2,833	236,876	—	—
From the South and East Coasts of England to the West Coast	2,255	173,797	—	—
From Ireland, to the South and East Coasts of England	1,103	99,290	—	—
From the South and East Coasts of England to Ireland	419	43,974	—	—
From the West Coast of England to Foreign Ports	746	85,627	685	105,690
From Foreign Ports to the West Coast of England	725	92,393	608	86,111
From Ireland to Foreign Ports	93	8,112	219	37,403
From Foreign Ports to Ireland	291	29,118	265	32,030
TOTAL	8,465	769,196	1,777	261,234
	Average size of Vessels, 91 tons each.		Average size of Vessels, 147 tons each.	

APPENDIX referred to in page 611.

STATEMENT of the NUMBER of VESSELS which have been wrecked or sustained Damage off the *Land's End*, or on or near to the Coasts of *Dorset*, *Somerset*, *Devon* and *Cornwall*, between *Bridgewater River* in the *Bristol Channel*, and the *Bill of Portland* in the *English Channel*, from 1815 to 1823, both Years included. Abstracted from the Books at *Lloyd's*.

YEAR.	Number of Vessels Stranded on the above-named Coasts, and either Damaged or totally Wrecked.	Number of Vessels that have lost their Masts, or sustained Injury at Sea, in their approach to or off the Land's End, and the above-named Coasts.
1815	51	76
1816	28	43
1817	42	64
1818	41	76
1819	35	57
1820	37	50
1821	49	70
1822	49	74
1823	50	48
	382	558
	Average, 42½ per ann.	Average, 62 per ann.

EXTRACT from LLOYD'S LIST, November 7th, 1823.

'The whole Coast from St. Ives to the Land's End is strewed with wreck, and it is impossible to ascertain the names of all the vessels that have suffered, as most of the crews are drowned.'

Note.—The collection of Extracts from the Books at Lloyd's, comprised in eighty-three folio pages, as made by Mr. William H. Scotland, and from which the above statement is abstracted, is deposited with Messrs. King and Lukin, solicitors to the proposed canal.

APPENDIX referred to in page 612.

STATEMENT of the DRAUGHT of WATER of VESSELS of different Sizes and Denominations, abstracted from the Evidence of the principal Ship-builders in the River *Thames*, as delivered before the Select Committee of the House of Commons upon the Improvement of the Port of *London*, and printed in the Appendix to their Report, dated 28th July 1800.

Designation.	Tons.	Vessels' Names.	Trade.	Draught when loaded.	Draught when in ballast.
				ft. in.	ft. in.
Sloop - -	100	Happy Return -	Corn - - -	9 –	7 –
Brig - -	100	Ashley - -	Yarmouth -	10 –	5 –
„ - - -	150	Betsey - -	America -	11 –	7 –
„ - - -	200	Good Intent -	Coal - -	13 –	8 –
„ - - -	250	Dolphin - -	Coal - -	14 6	9 –
Ship - -	200	Adriatic - -	West Indies	12 –	7 –
„ - - -	286	Mars - - -	Coal - -	15 –	9 –
„ - - -	300	Content and Peace	Coal - -	15 7	9 6

APPENDIX (R. 1.)

REPORT of the COMMISSIONERS appointed by HIS MAJESTY to inquire into the state of the SUPPLY of WATER in the METROPOLIS.

IN obedience to the commands contained in His Majesty's Commission, directing us to inquire into the state of the Supply of Water in the Metropolis, and to report our observations and opinions touching and concerning the same, we proceeded without delay, as soon as the arrangements necessary for executing them could be completed, to investigate the important subject referred to us. The circumstances which prevented our meeting

for the purposes of that inquiry until December last are stated in our correspondence with the Secretary of State for the Home Department, which is contained in the Appendix to this Report. From the terms of our Commission, and from the tenor of the petitions of the inhabitants of the western portion of the Metropolis, and of the Borough of Southwark, to both Houses of Parliament, referred to our consideration, praying for an inquiry into the quality of the water furnished by the Water Companies, and into the means of procuring an effectual and permanent supply of pure and wholesome water, as well as from the communications with His Majesty's Principal Secretary of State for the Home Department, it appeared that our attention was required to be directed to three principal points; namely, first, to ascertain the sources and means by which the Metropolis is supplied with water, and their efficiency as to the quantity supplied; secondly, to determine the quality of the water; and, thirdly, to obtain such information as might enable us, if necessary, to suggest new methods, or sources of supply, or to point out the means of ameliorating those now in existence. But having since learned, by a recent communication from His Majesty's Principal Secretary of State for the Home Department, that our inquiry is to be limited to the description, the quality and the salubrity of the water, and that we are not called upon either to consider new and more eligible sources of supply, or to suggest plans for the improvement of those already existing, we have agreed upon the following Report, respecting the two former subjects.

In investigating the supply of water in respect to quantity, we proceeded, in the first instance, to collect the requisite information as to the powers and resources of the different water companies upon the north side of the Thames; first procuring evidence from the companies themselves as to the extent and facilities of their supplies, and afterwards checking such evidence by collateral testimony from other witnesses, and occasionally by personal examination into the facts.

The supply of this, the most extensive portion of the Metropolis, is dependent upon five companies, which, arranged in the order of the number of tenants they serve, and nearly in that of the quantity of water which they respectively furnish, stand as follows:—

The New River,
The East London,
The West Middlesex,
The Chelsea, and
The Grand Junction Companies.

Of these companies the *New River* derives its principal supplies of water from a spring at Chadwell, between Hertford and Ware, and about twenty-one miles north of London; and also from an arm of the river Lea, the source of which is near the Chadwell spring, in the proportion of about two-thirds from the former, and one-third from the latter. These united waters are conducted by an artificial channel nearly forty miles in length, to four reservoirs, called the New River Head, at Clerkenwell; proper means being adopted to prevent the ingress of fish and weeds, and such arrangements being made in respect to the mains as to prevent interruption of service in case of repairs. Since, however, the

abandonment of the London Bridge, and of the York Buildings Water-works, whose former districts are now supplied by the New River Company, they have found it advisable to erect an engine at Broken Wharf, Thames-street, by which they are enabled occasionally to supply parts of their district with Thames water, when, from long-continued droughts, severe frosts, or other accidental causes, the flow of the New River is impeded. It appears, however, that the quantity of Thames water thus supplied bears a very trifling proportion to the other source, the engine at Broken Wharf having been worked for seventy-six hours only in January and February of last year, and for one hundred hours during the drought of July and August. The number of tenants supplied by the New River Company is between sixty-six thousand and sixty-seven thousand, and the quantity of water which is daily supplied exceeds thirteen millions of gallons, being about two millions of cubic feet.

The *East London Water-works* are situated at Old Ford, on the river Lea; but as the tide of the Thames flows up that river to the extent of a mile beyond the works, and as their supplies are taken during the ascending tide, the description of water thus furnished will closely approximate to that of the Thames. This Company has four reservoirs; the number of tenants supplied amounts to about forty-two thousand, and the daily consumption of water to nearly six millions of gallons, or about nine hundred and fifty thousand cubic feet.

The *West Middlesex Water-works* are upon the banks of the Thames, at the upper end of Hammersmith, and draw water exclusively from that river, opposite to the works. They have two reservoirs, one at Kensington, and one at Little Primrose Hill, which are supplied by the engines at Hammersmith, and they serve about fifteen thousand tenants. The average daily consumption of water is two million two hundred and fifty thousand gallons, or about three hundred and sixty thousand cubic feet.

The *Chelsea Water-works* are upon the banks of the river, about a quarter of a mile east of Chelsea Hospital; and their supplies are derived entirely from the Thames opposite to their works. They have two reservoirs, one in Hyde Park, and one in the Green Park, close to Piccadilly. They supply about twelve thousand four hundred houses; the average daily supply to the whole being about one million seven hundred and sixty thousand gallons, or nearly two hundred and eighty-two thousand cubic feet.

The works of the *Grand Junction Company* are also at Chelsea, immediately adjacent to, and east of, the Hospital. They derive the whole of their supply of water from the river Thames, with which they fill three reservoirs situated at Paddington, and from these their district is served. The number of their tenants does not appear to exceed seven thousand seven hundred; but their daily consumption of water is about two million eight hundred thousand gallons, or upwards of four hundred and fifty thousand cubic feet.

It appears from this statement that the portion of the town upon the north side of the river Thames, including the cities of London and Westminster, is supplied daily with a quantity of water amounting to nearly twenty-six millions of gallons, and that the total number of houses and buildings receiving this supply amounts to about one hundred and

forty-four thousand. The water is of course very unequally distributed, the average consumption in each house being apparently greatest in the district supplied by the Grand Junction Company, where it amounts to about three hundred and sixty-three gallons daily per house. Taking the average of the whole supply, the daily consumption of each house is about one hundred and eighty gallons.* Of this water, more than one-half of which is derived from the Thames, a large portion is delivered at very considerable elevations above the level of the river, constituting what is called high service; for which purpose fifteen steam-engines are employed, exerting a power of about one thousand one hundred and five horses.

It is obvious, from the above statement, that the quantity of water supplied in London and Westminster is abundant; and in our examinations of individuals touching the quality of the water, we have in no instance met with complaints of deficiency in quantity. We have reason to believe that the hospitals, workhouses, and other similar establishments, where an abundance of water is an essential requisite, are in all cases duly supplied; and upon the important subject of supply in case of fire, our evidence leads us to believe that of late it has always been ample, and that when not immediately procured, the fault has lain with the turncocks; for among other advantages of the reservoirs annexed to the works upon the Middlesex side of the river, is that of having at command a large head of water, by which the mains are kept full, and in many districts are under considerable pressure. The supply of a large quantity of water upon any sudden emergency is thus ensured; and among other great advantages arising out of the substitution of iron for wooden mains, is that of their sustaining the pressure of a column of water which it would have been impossible, in the former state of the works, to have commanded.

As far therefore as regards the description and quantity of water supplied to the cities of London and Westminster, it appears that more than half the consumption is derived from the Thames, and that it is in such abundance as not only to supply all necessary demands upon ordinary and extraordinary occasions, but that a proportion is constantly suffered to run to waste, by which the cleansing of the drains of houses and of the common sewers is effectually accomplished, all accumulations of filth obviated, and the general healthiness of the metropolis promoted.

We next proceeded to examine into the supply of water to those parts of the metropolis situated upon the south side of the river, including the borough of Southwark. We found that they are dependent upon three establishments, known as

The Lambeth,
The South London, and
The Southwark Water-works.

The first of these is upon the banks of the Thames, between Westminster and Waterloo bridges, drawing its supplies from the river immediately opposite to the works.

* The Population of that part of the metropolis situate north of the river Thames, is now known to have been 1,050,000 in the year 1827–8; so that the supply of water was then arrived at twenty-five gallons per day for each individual; it is supposed to have much increased since that time.—EDITOR.

They have no reservoir, the water being forced immediately from the river into the mains, and thence distributed to about sixteen thousand tenants, who consume one million two hundred and forty-four thousand gallons daily, or nearly two hundred thousand cubic feet.

The *Vauxhall* or *South London Water-works* are situated in Kennington-lane, and have also an engine on the river at the foot of Vauxhall bridge. They supply Thames water exclusively, and have reservoirs for the service of their upper engine. The number of their tenants is about ten thousand, and the daily consumption of water about one million of gallons, or about one hundred and sixty thousand cubic feet.

The *Southwark Water-works* are upon the bank of the river, between Southwark and London bridges, and derive the whole of their water from the middle of the river opposite to their engines. It appears that about seven thousand tenants are supplied by this establishment with about seven hundred and twenty thousand gallons of water, or one hundred and fifteen thousand cubic feet daily.

Each of these establishments has two engines; the aggregate power of the six may be estimated at about two hundred and thirty-five horses. The whole of the water which they supply amounts to nearly three millions of gallons, or four hundred and eighty-five thousand cubic feet daily, which is distributed among thirty-three thousand tenants.

There appear to be no just complaints respecting the quantity of water furnished by any of these companies, except in cases of fire, when there has occasionally been a serious deficiency. We have inquired into the causes of this, and are induced to refer it to the want of proper reservoirs for preserving a head of water upon the mains when the engines are not working. On these occasions much time is often lost in sending to the engine of the district, and if the steam be not up, and the fire low, further and fatal delay sometimes occurs.

In reference to the total amount of the quantity of water required for the daily supply of the inhabitants of the metropolis, and for the use of the various manufactories requiring it, it appears to be about twenty-nine millions of gallons, or four million six hundred and fifty thousand cubic feet.

We next directed our attention to such facts respecting the quality and salubrity of the water with which the inhabitants of London are supplied, as were in our judgment best calculated to enable us to form a correct and unprejudiced opinion upon this important question. Being a question, however, in which the interests of a great number of individuals and public bodies are deeply involved, and which has been the subject of acrimonious controversy, and also respecting which a variety of representations had gone forth to the public, we perceived that it would necessarily embrace a multitude of considerations of a delicate and complicated nature. We felt it to be our duty, therefore, to begin by dismissing from our minds whatever previous impressions might have been received from the reports and statements which had been circulated, and to be guided in our judgment solely by the evidence we should be enabled to obtain in the execution of our commission.

In our remarks upon this evidence, we shall first confine ourselves to the water of the river Thames.

Assuming the supplies to be derived directly from the river, and to be subjected to no intermediate process tending to purification, it is sufficiently obvious that the state of the weather will materially affect the purity of the water, which is sometimes comparatively clean and clear, and at others loaded with various matters in mechanical suspension, rendering it more or less coloured and turbid. In the latter state, when thrown into cisterns and other receptacles of houses, it is manifestly unfit for immediate use; but after being allowed to rest, it forms a certain quantity of deposit, and thus may become sufficiently clear for ordinary purposes. This deposit, however, is the source of several evils; it renders the cisterns foul, and runs off into those pipes which issue from or near the bottom of the reservoirs. By the agitation which accompanies every fresh influx of water, this deposit is constantly stirred up, and becomes a renewed source of contamination to the whole mass; and, although chiefly consisting of earthy substances in a state of minute division, it is apt also to contain such proportion of organic matters as will occasion a degree of putrefaction when collected in any quantity, and especially in warm weather. Of this deposit more or less is almost always collected, especially where the service is direct from the river; and although some of the companies have reservoirs of such magnitude as to enable them to serve water already partially purified by deposition, the system is still very imperfect, and the water is frequently supplied in a turbid state. In other cases, the companies' reservoirs, however eminently useful in cases of fire, become objectionable in regard to the purity of the water, since the mud accumulates in them, and also proportionately in the mains and branch pipes.

By far the greater number of complaints which have been made to us with respect to the quality of the water have originated in the cause just alluded to, and hence some of the companies have attempted to get over the difficulty by suffering the water to remain at rest for a sufficient time to become clear before the public are supplied, and in this they have in some instances so far succeeded as materially to improve their service. When, however, from land floods or other causes, the river is very thick, they cannot allow due time for such subsidence; and even when most perfectly performed, the insects contained in the water, so far from being got rid of, become, perhaps, even more numerous. This is another just cause of complaint in regard to the water, especially in hot seasons.

To obtain an effectual supply of clear water, free from insects and all suspended matters, we have taken into consideration various plans for filtering the river water through beds of sand and other materials; and considering this, on many accounts, as a very important object, we are glad to find that it is perfectly possible to filter the whole supply, and this within such limits, in point of expense, as that no serious objection can be urged against the plan on that score, and with such rapidity as not to interfere with the regularity of service.

It must, however, be recollected that insects and suspended impurities only are separated by filtration, and that whatever substances may be employed in the construction of filtering beds, the purity of the water, as dependent upon matters held in a state of

solution, cannot be improved by any practicable modification of the process. If, therefore, it can be shewn that water taken from the parts of the river whence the companies draw their supplies, either is, or is likely to be, contaminated by substances dissolved, or chemically combined, it will follow that the most perfect system of filtering can effect only a partial purification.

From the commencement of our inquiries we have bestowed considerable attention upon this subject, and have endeavoured to obtain accurate information respecting it. But on examining such analyses of the water as had already been made, and were communicated by the companies, as well as by several individuals of high authority on these matters, we found them to be so far at variance with each other as to prevent our drawing from them satisfactory conclusions. We, therefore, devised a more regular plan of procedure, which we conceived would be better suited to the particular objects of our present inquiry. After all the preparations for that purpose were completed, the occurrence of a heavy fall of snow, the effects of which on the water of the river would have introduced uncertainty in the results, induced us to defer for a time the execution of our plan. We waited till the river had returned to what may be regarded as its average state, and under these circumstances, directed portions of water to be taken, under the personal inspection of our secretary, from different parts of the river at different times of the tide, and especially from those parts whence the companies draw their water; and also from situations higher up the river, where its quality can in no degree be influenced by the tide. With the view of comparing the state of the Thames water at London under different circumstances, we subsequently procured specimens from several parts of the river after an abundant fall of rain; and also others from places where it had been represented to us as particularly charged with impurities. A popular notion having prevailed that the water in the London Dock possessed peculiarly deleterious qualities, from an impregnation of copper derived from the bottoms of the ships, we likewise obtained, with a view to inquire into the truth of this opinion, portions of water from the dock, taken at three different depths from the surface.

In order to ensure the subjecting of all these various specimens to the most careful and rigid examination upon one uniform system, we put them, for that purpose, into the hands of Dr. Bostock, a gentleman eminently qualified for the task by his extensive knowledge of chemistry, and his practical experience in this department of analysis. In the Appendix will be found a detailed account of his examinations, in the accuracy of which we have every reason to repose the fullest confidence. In this report to us, he justly remarks that it would have required a much longer space of time than was allowed him to have performed a complete scientific analysis of so many specimens of water; but the results he obtained are quite sufficient for the object proposed, and to which we more particularly directed his attention, namely, 'to ascertain how far the water of the Thames, 'contiguous to, or in the neighbourhood of, London, is in a state proper for being employed 'in diet and various other domestic purposes.'

The general conclusion he deduces from the whole series of examinations is expressed in the following passage of his Report:—

'It appears that the water of the Thames, when free from extraneous substances, is in 'a state of considerable purity, containing only a moderate quantity of saline contents, 'and those of a kind which cannot be supposed to render it unfit for domestic purposes, 'or to be injurious to the health. But as it approaches the metropolis it becomes loaded 'with a quantity of filth, which renders it disgusting to the senses, and improper to be 'employed in the preparation of food. The greatest part of this additional matter appears 'to be only mechanically suspended in it, and separates by mere rest. It requires, how-'ever, a considerable length of time to allow of the complete separation; while, on account 'of its peculiar texture, and comminuted state, it is disposed to be again diffused through 'the water by a slight degree of agitation, while the gradual accumulation of this matter 'in the reservoirs must obviously increase the unpleasant odour and flavour of the water, 'and promote its tendency to the putrid state.

'It would appear, however, that a very considerable part, if not the whole, of this 'extraneous matter may be removed by filtration through sand, and still more effectually 'by a mixture of sand and charcoal. Two bottles were sent to me for inspection, one 'containing the water of the Thames, (I believe taken from the neighbourhood of Chelsea,) 'the other containing water from the same source, [*see* Appendix (R. 3.)] after having 'been filtered through a bed of sand; the former exhibited the usual appearance, while 'the latter was perfectly free from visible impurities and had lost all unpleasant flavour 'or odour. I think, therefore, we may conclude, that the process of filtration, if properly 'conducted, would be in all respects unexceptionable, provided a sufficient quantity of 'water could be prepared by this means for the supply of the Metropolis.'

The examination of the water taken from the London Dock shewed that it did not contain the smallest appreciable quantity of copper.

We have also endeavoured to gain information from various other sources respecting the state and purity of the Thames water, and its general fitness for domestic use; and from such inquiries it appears proved to us that the quality of the water within certain limits, included in what may be called the London district, has suffered a gradual deterioration within the last ten or twelve years. We found this opinion upon the well-ascertained fact of the disappearance of fish from those parts of the river, to such an extent as to have led to the almost entire destruction of the fisherman's trade between Putney Bridge and Greenwich; and upon the circumstance that the eels imported from Holland can now with great difficulty be kept alive in those parts of the Thames where they were formerly preserved in perfect health. We also learn that the fishmongers in London find it impossible to preserve live fish for any length of time in water taken from the same district.

The causes of these effects are, perhaps, principally to be traced to the increase of certain manufactories, amongst which those of coal-gas are the most prominent, polluting the river by their refuse; to the constant passage of steam-boats, by which the mud is stirred up, and to the peculiar nature of that mud within the above-mentioned precincts. The very circumstance, also, of the great abundance with which water is supplied to the houses and manufactories of the metropolis, appears to be essentially connected with the aug-

mented impurity of the river; for where refuse animal and vegetable matter of various descriptions used to be collected, and from time to time removed for the purposes of manure, it is now indiscriminately washed into the sewers, and conveyed into the Thames; and the sewers themselves are rendered much cleaner than formerly by the quantity of water which runs to waste, and which, as already remarked, has rendered them less offensive, especially in those parts of the town where they used to be most liable to stagnation and consequent putrescence. Thus it has been stated to us that the water of the river is more polluted immediately after heavy rains, which force down the contents of the sewers, than after a continuance of dry weather, when its course is sluggish or altogether arrested; and the results of experiments we directed to be made on the subject fully establish this fact. The great increase which has of late years taken place in the population of London, and of its suburbs on every side, must also be attended by a proportionate augmentation in the quantity of extraneous matter carried down into the Thames.

There are other circumstances affecting the fitness of the water, as now taken from the river for the supply of the town, which, though less general in their influence, should not be overlooked; such as the position of the suction pipes of the engines belonging to some of the companies in regard to the mouths of sewers, the quantity of dead animals thrown into the river in and about London, its contamination by the offal of slaughter-houses, and a variety of other causes, which we need not here specify, but which will be found on reference to the evidence. Some of these we have inquired into in detail, and have anxiously sought for means by which the nuisances in question might be remedied or abated; but it is manifest that if the general quality of the river water be objectionable within the whole of that district whence the supplies for the metropolis are drawn, any remedies for local evils become comparatively unimportant; and although these diminish as we ascend the river, we apprehend that their influence with that of the other contaminating causes will be more or less felt nearly to the extent to which the tide reaches.

The statements which have been made respecting the insalubrity of the Thames water, as supplied by the companies, have also been considered by us; and, although from the few cases which have been brought before us of disorders imputed to this cause we do not feel ourselves warranted to draw any general conclusions, we think the subject is by no means undeserving of further attention. There must always be considerable difficulty in obtaining decisive evidence of an influence, which, although actually operating to a certain extent as a cause of constitutional derangement, may yet not be sufficiently powerful to produce immediate and obvious injury. It cannot be denied that the continued use of a noxious ingredient in diet may create a tendency to disorders, which do not actually break out until fostered by the concurrence of other causes; for we unquestionably find an influence of the same kind exerted by other agents, which occasion merely a certain predisposition to disease, and of which the immediate operation must therefore be extremely insidious and difficult to trace. It is obvious that water receiving so large a proportion of foreign matters as we know find their way into the Thames, and so far impure as to destroy fish, cannot, even when clarified by filtration, be pronounced entirely free from the suspicion of general insalubrity. In reference also to this question, we

apprehend that there are no grounds for assuming the probability of any improvement in the state of the water drawn from the London district of the river.

Although the principal supply of water by the New River Company is not open to the same objectionable impregnations as that of the Thames, we think it, nevertheless, susceptible of much improvement. The occasional deficiency in quantity, which suggested the necessity of the engine at Broken Wharf, might be obviated by allowing a portion of that supply to be drawn from the river Lea at Lea Bridge.

But here, as in respect to the Thames, the water is occasionally very muddy, receiving as it does the drainage of a considerable extent of country, in consequence of a right claimed by the proprietors of adjacent lands, and which the Company have at present no means of obviating; neither have they any power to prevent persons from bathing in their aqueduct.

These evils they would very gladly remedy if enabled to do so; and their removal, together with the adoption of an extensive system of filtration, would materially contribute to the perfection of the New River supply. Great benefit would result, not only to the extensive district of London supplied by this Company, but also to the public at large, if the inducement to bathe in the open canal of the New River were superseded by the establishment of baths in the neighbourhood of the metropolis, to which the public might, under certain regulations, be allowed access. It has been stated to us in evidence that the New River Company have voluntarily offered to furnish sufficient supplies of water for a purpose of such manifest and general utility.

Taking into consideration the various circumstances to which we have now adverted, together with the details of evidence by which they are proved and illustrated, and also the facts derived from our own observation and experience, we are of opinion that the present state of the supply of water to the metropolis is susceptible of, and requires, improvement; that many of the complaints respecting the quality of the water are well founded, and that it ought to be derived from other sources than those now resorted to, and guarded by such restrictions as shall at all times ensure its cleanliness and purity.

Various schemes, proposed by different individuals for the attainment of these desirable objects, have occupied our attention in the course of our inquiries; but the complete examination of any plan of this kind, with reference to its practical efficiency and expediency, would necessarily have required the taking of surveys of the ground, and the determination of levels of different points comprehended in such plan. The limits which have been assigned to our inquiry, and the manner in which our Report has been demanded, have precluded such further investigation of this important subject as we had originally contemplated, and for which, indeed, we had been making preparation. But while we must, consequently, refrain from any further remarks upon the remedies applicable to the existing evils, and upon the best means of conveying a sufficient supply of water of unexceptionable quality to the inhabitants of the metropolis, we are unwilling to close our labours without expressing our strong sense of the importance of this object

to the public, and our earnest hope that its full investigation by competent persons will not be long deferred. As, however, the materials we had collected with a view to this more extended inquiry may still be useful to those by whom the inquiry is resumed, we have thought it proper to insert them in the Appendix to this Report. Some part of the evidence offered to us by one of the companies, relating to projected alterations and improvements, and which was not in a sufficiently mature state to be made public, has, at the request of that company, been withdrawn, on their finding that we had not the power of prosecuting the inquiry to the extent originally contemplated.

We have not entered into the question of the effects resulting from the mutual compact agreed upon by the several Water Companies on the Middlesex side of the Thames, with regard to the limitations of the districts they respectively supply; it having been expressly stated to us by His Majesty's Principal Secretary of State for the Home Department, at the time our Commission was issued, that the grievances imputed to this cause were not to form any part of our present inquiry; inasmuch as they had been the special subject of consideration by a Select Committee of the House of Commons, appointed for that purpose in the year 1821, and by whom a Report relating to those matters has been made. The opinion given by that Committee was, that in consequence of the peculiar nature of the undertakings of companies for the supply of water, where large capitals must necessarily be vested in fixed machinery, and where, from the commodity furnished being of no value, but for consumption on the spot, the sellers are confined to the market by the nature of the trade, the principle of competition in its application to such companies requires to be guarded by particular checks and limits, in order to render it effectual without the risk of destruction to the competing parties, and thereby ultimately of a serious injury to the public. The only remark we shall venture to make upon this subject is one naturally suggested by the evidence which has come before us in the course of our inquiries; namely, that if on the one hand, the preservation of the present Water Companies, from which the public have undoubtedly derived immense benefits, would be endangered by unlimited competition with new companies that might be established for similar objects,—it must, on the other hand, be evident, when due regard is had to the consideration, that the constant and abundant supply of pure water is an object of vital and paramount importance to the inhabitants of this vast metropolis, that the dispensing of such a necessary of life ought not to be altogether left to the unlimited discretion of companies possessing an exclusive monopoly of that commodity; and that the interests of the public require that, while they continue to enjoy that monopoly, their proceedings should be subjected to some effective superintendence and control.

P. M. ROGET, (L. S.)
WILLIAM THOMAS BRANDE, (L. S.)
THOS. TELFORD, (L. S.)

9, New Palace Yard, Westminster,
April 21st, 1828.

Appendix (R. 2.)

REPORT of *Thomas Telford*, Civil Engineer, February 1834, on the Means of supplying the Metropolis with Pure Water.

To the Right Honourable the Lords Commissioners of His Majesty's Treasury.

Having received directions from the Lords Commissioners of His Majesty's Treasury to report upon the means of supplying the Metropolis with pure water, I immediately proceeded in the investigation of this important object, and after extensive and repeated surveys, and much consideration, beg leave to make the following Report:—

The water of the river Thames being strongly objected to by the inhabitants of this great city, and also condemned in the Report of the Commissioners of Water Inquiry [*see* Report, 21 April 1828, page 631*], in consequence of the impurities with which it is contaminated; I therefore perambulated the district on each side of the valley of the Thames, and examined the streams which fall into that river in the vicinity of London.

In the result I found an abundance of pure, transparent water, within the distance of sixteen miles on the north, amply sufficient for the supply of three of the present water companies on that side of the Thames; and within ten miles on the south, I found as ample a supply for the three waterwork companies on the south side of the river, at a sufficient elevation for both high and low services, without having recourse to filtration, or indeed to pumping, except for a small portion of the high services.

The circumstances of the two companies supplied with water from the valley of the river Lea, require to be spoken of separately. What relates to the companies which supply water to the north-western parts of the metropolis shall first be discussed: these are, the West Middlesex, the Grand Junction, and the Chelsea Companies.

From information obtained by the Commissioners of Inquiry in 1828, the daily supply of water, on an average throughout the year, afforded by each company, was as follows:

The Grand Junction - - -	2,800,000	gallons.
West Middlesex - - -	2,250,000	-
Chelsea - - - - -	1,760,000	-
In all - - -	6,810,000	gallons, or

one million eighty-nine thousand six hundred cubic feet per day, equal to seventy-eight thousand eight hundred and nineteen gallons, or (nearly) thirteen cubic feet per second.

* 'Taking into consideration the various circumstances to which we have now adverted, together with the details of 'evidence by which they were proved and illustrated, and also the facts derived from our own observation and experience, we 'are of opinion that the present state of the supply of water to the metropolis is susceptible of, and requires, improvement; 'that many of the complaints respecting the quality of the water are well founded, and that it ought to be derived from other 'sources than those now resorted to, and guarded by such restrictions as shall at all times ensure its cleanliness and purity.'

At the town of Uxbridge, the whole of the river which passes that place is called the Colne, with which a considerable stream, called the Chesham, forms a junction at Rickmansworth: proceeding upwards, between Rickmansworth and Watford, the westerly branch occupies the Berkhampstead valley, and the eastern branch, called the Verulam, a transparent stream, occupies the St. Alban's valley; and about half-way between St. Alban's and Watford, the Colne joins the Verulam; but, unless after heavy rains, the Colne is an insignificant stream, and at such times very muddy; wherefore it is intended to exclude the Colne from furnishing any part of the supply of water to the metropolis.

At Watford Mill, in the autumn of 1833, being the driest season, as regards the supply of rivers, experienced during the last half century, the Verulam river produced upwards of thirty cubic feet of water per second; being more than double the quantity supplied by the three companies in the year 1828, namely, thirteen cubic feet per second, as before stated.

In the Berkhampstead valley, the river Gade, at Hunton Bridge (three miles north of Watford), in the same dry season produced forty-two cubic feet per second; but to connect the Gade with the Verulam would cost £. 50,000, a heavy expense, which, however, is a small objection compared to the turbid state of the Gade water, produced by its connection with the Grand Junction Canal, and the more decided cause for rejecting it altogether, from its being infected by the deleterious substances used at the paper-mills: so that there being abundance of clear water produced by the Verulam alone, at a sufficiently high elevation, I propose to avoid these annoyances altogether.

Immediately above the commencement of the intended London aqueduct, about two miles above Watford, the valley of the river Verulam affords a commodious situation for extensive reservoirs of water, and for allowing it to settle, if such should hereafter be deemed requisite.

From this place a covered aqueduct may be made to descend with a uniform inclination of eighteen inches per mile to Primrose Hill, terminating in a set of extensive receiving and distributing reservoirs, at the height of one hundred and forty-six feet above high-water, Trinity datum standard, in the river Thames; from these reservoirs each of the three before-mentioned companies may be supplied separately, and in such proportion as shall be determined.

In order to deliver the water into the reservoirs near Primrose Hill in the same state of purity as it leaves the Verulam river, it is proposed to conduct it through a covered aqueduct, at such a depth under the surface of the ground as to be secure from the effect of frost, from any mixture of surface water, and from external injury by cattle or otherwise; and to preclude the unavoidable interruptions occasioned by cleansing the waterway and effecting repairs, this aqueduct will be constructed with a double watercourse, separated by a footpath throughout its whole length.

South of the valley occupied by the Colne and Verulam, there is a narrow ridge of land, through which the aqueduct must pass by means of tunnelling; but as this ridge consists of a mass of chalk, no difficulty is to be apprehended in this operation.

I have thus given the outline of the plan I recommend, by which three of the companies on the north side of the river Thames may obtain a plentiful supply of pure water. It has already been mentioned, that in 1828 these three water companies distributed about thirteen cubic feet of water per second, on an average, throughout the year; but as the maximum demand of the summer months is stated to be twenty-five per cent. more than the average throughout the year, the maximum rate of supply by these three companies, in 1828, appears to have been sixteen and a quarter cubic feet per second; in the five years since that period, the quantity distributed is said to have been increased twenty-five per cent., partly from the increase of population and partly owing to the larger demands of the inhabitants: thus I shall assume the maximum rate of demand in 1833 to be twenty cubic feet per second.

To provide for this and any future increase of water expenditure, I propose to obtain thirty cubic feet of water per second from the river Verulam, which is ten cubic feet more than the maximum demand in the middle of summer. And if at any future period even a greater quantity should be required, reservoirs may be made for retaining the superfluous water of the Verulam, to ensure a proportionate supply; wherefore I propose that the London aqueduct should be made sufficiently large to convey an extra quantity; and that the whole of the water yielded by the river Verulam be secured for supplying the metropolis with water, should it ever be required.

South Side of the Thames.

The daily supply afforded by the three companies on the south side of the river Thames, on an average throughout the year, according to evidence produced to the Commissioners in 1828, was as follows:—

The Lambeth Company - - -	1,244,000 gallons.
South London - - - -	1,000,000 –
Southwark Waterworks - -	720,000 –
	2,964,000 gallons.

This is equal to four hundred and seventy-four thousand two hundred and forty cubic feet daily, or at the rate of five and a half cubic feet per second.

Thus the three companies distributed in 1828 not quite six cubic feet of water per second, all derived immediately from the river Thames.

The supply on this side of the river being under the same circumstances as that on the north side already described, and requiring similar additions for the summer supply and for general increase during the five years elapsed since that time, the present maximum supply in the summer months may be assumed at eight and a half cubic feet per second; to provide for this and any future increased demands, I propose to secure thirteen cubic feet per second.

The best means of obtaining an ample supply of pure transparent water for these three companies is by taking it from the river Wandle at a sufficiently high elevation, which is found on the Croydon branch of that river, at the east end of Beddington Park, ninety feet above high-water in the river Thames. From this place an aqueduct may be carried in nearly a direct line to Clapham Common, and there terminate in a requisite number of reservoirs at a height of eighty-two feet above high-water in the river Thames, which, except Brixton Hill (supplied by the Lambeth Company), exceeds the present heights of delivery by the several companies, which are as follows:—

Lambeth - - - -	42 feet.
South London - - -	65 –
Southwark - - - -	56 –

The proposed reservoirs on Clapham Common will therefore ensure a sufficient elevation.

The main branch of the river Wandle takes its rise in a singularly copious spring in the vicinity of Croydon, and, after pursuing a westerly course for about three miles, is joined by the Carshalton branch, which likewise derives its origin from several plentiful springs in that neighbourhood.

The water of this river possesses at all times an uncommon degree of purity, regaining its transparency after the heaviest rains in the course of a few hours.

The quantity of water flowing down the Carshalton branch of the river Wandle in the extraordinarily dry season of 1833, was at the rate of thirteen cubic feet per second; the quantity discharged by the Croydon branch at the same time was at the rate of seventeen cubic feet per second. From this last I propose to take thirteen cubic feet per second, being four and a half cubic feet per second beyond the present maximum demand in the middle of summer.

From the Clapham reservoirs all the three companies may be supplied separately, and in such proportion as shall be afterwards decided, at eighty-two feet elevation above high-water mark, Trinity standard. The new houses on Brixton Hill would be supplied with pure water by eighty-two feet less expense of pumping than what is at present required for this purpose.

In all the works of the six before-mentioned companies, on both sides of the Thames, some expense must be incurred in extending and adapting their mains for the reception of pure water. The quantity and method of appropriating the supply, so as to satisfy the demands of all parties, being regulated in such manner as shall, upon conferring with the engineers of the different companies, be deemed most advisable.

Expense and Remuneration.

Having shown by what means the Metropolis may be amply supplied with pure water by six of the present water companies,* without disturbing their present works, at an expense of about £. 1,177,840. 16 *s.* 5 *d.*, including the construction of reservoirs, covered

* See Appendix, p. 644.

aqueducts and connecting mains, also making compensation for water taken from mills (by substituting steam-power in lieu thereof), and the value of land and damages, I conceive that I have performed the duty imposed upon me by the Lords Commissioners of His Majesty's Treasury; that is, 'In what manner the metropolis can be supplied with 'pure water.' The manner in which any advance on the part of the public is to be repaid, being a matter of finance, I leave to be determined by others, and shall only annex a copy of what was recommended by the directors of the Grand Junction Waterworks Company,* viz. they suggest that the 'only course that could be pursued to avoid a ruinous waste 'of capital, and a consequent loss to the public, is, that the Commissioners should be 'directed to ascertain the best mode of obtaining the supply required; that Government 'should advance the sum requisite to bring the water to the spot from whence the 'companies could receive it into their several works, upon the security of their respective 'incomes, as has been done in other public undertakings; that the outlay should be under 'the supervision of some Parliamentary authority, and that the increase of rates to be 'charged by each company should be no more than the proportion of interest they should 'respectively pay to Government.'

This seems a fair and judicious proposal; and as a constant annual outlay for pumping and filtration will be saved to the water companies, this sum, and any other that can be saved, would be appropriated towards payment of the interest on the Government expenditure for the new works. By this arrangement only a moderate addition to the present rates will be necessary; and it is presumed that the inhabitants would willingly agree to this new rate being established, thus ensuring to themselves a plentiful supply of pure water.

In order that the necessary works may be performed in a satisfactory manner, and that the water may be correctly supplied, in quantity and quality, to each company, a Parliamentary Commission (as recommended by the Grand Junction Company) should be appointed to manage the whole.

It may be of use to remark, that the course of these aqueducts, on both sides of the river, interferes with no private dwelling or public establishment of any kind; and the same observation is applicable to all the reservoirs proposed in this Report; and as the aqueduct will also be under the surface of the ground for the greater part of the distance, the chance of derangement, after being completed in a perfect manner, is not to be anticipated.

It should also be stated, that all the changes recommended in this Report may be accomplished without interfering with any of the present establishments. When the new works are completed, and the water ready for delivery, the different companies will have only to shut off communications with the river, and open the pure water supplies; and this is an important advantage, considering the incessant demand for one of the necessaries of life, which admits not of interruption during a single day or hour.

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* *See* Report, 11 March 1830.

Until the public have by experience acquired a perfect confidence in the quantity, quality and regularity of the pure water supply, the communication with the river ought to be preserved, but not used unless necessity for doing so should occur.

The New River.

It seems unnecessary to go into a history of this magnificent work, from which the Metropolis derives so great a portion of its supply of pure water, it being well known to have been accomplished by Sir Hugh Myddleton in the reign of James the First, after encountering many difficulties, and not without his royal assistance. I shall therefore confine my observations to its present state.

The river Lea is the drain of a valley in the great chalk ridge which intersects the county of Hertford. This is a considerable stream adjacent to the town of Hertford, and in its progress towards the Thames, by Waltham Abbey, its waters are much augmented by a junction with its tributary streams, the Ash and Stort, which fall into the main river some distance below the town of Ware.

In the valley of the Lea, and in the neighbourhood of Ware, two singularly copious springs issue from the foot of the Chalk Hills. The upper and greater is named the Chadwell Spring; the other, which is below the town of Ware, the Amwell. The quantity and transparency of these springs were the inducements for taking the water from this place for the supply of the metropolis; more especially as the position was found sufficiently high to enable the projectors to carry the water along a very circuitous artificial aqueduct of thirty-seven miles in length to the suburb of Islington, where it terminates at the height of eighty-four feet above the river Thames, whence it is distributed over a large district; and, having been maintained with great care and expense, has afforded an ample supply of water to the inhabitants.

But during two centuries the population of the metropolis has greatly increased, and along the whole length of the aqueduct, villages and splendid mansions have arisen, so that the consumption of water has also greatly increased; wherefore, by several Acts of Parliament, authority has been granted for drawing an additional quantity from the river Lea.

In the distribution of the water produced in the valley of the river Lea, three objects require attention:

1st. The supply of a great portion of the metropolis with pure water.

2d. The navigation of the river Lea between the town of Hertford and the Thames.

3d. The water power of the mills upon the river Lea, including the Government mills at Waltham Abbey.

An ample supply for the metropolis ought certainly to be secured in the first instance, because the two other objects may, if absolutely necessary, be otherwise provided for; moreover, upon investigating the subject, I am convinced that, by judicious arrangement, all these three purposes may be combined and accomplished.

The appropriation of the water of the Lea has, during the last century, been the subject of much litigation, and the most eminent engineers, viz. Sir Christopher Wren, Desaguiliers, Smeaton and Rennie have been employed; and, lastly, the supply of water and the comparative levels have been carefully ascertained under my direction.

Upon consideration of the entire subject, I am of opinion that the law, as it now exists, ought not to be disturbed.

I also understand that since the year 1828 conferences have taken place, and the outline of a scheme suggested, which, with such modification as existing circumstances require, would be satisfactory to all parties concerned; and this, I hope, will be completed without delay.

The quantity of water delivered to the inhabitants of London and its vicinity by the New River Company, as stated to the Commissioners of Water Inquiry in 1828, was at the rate of twenty-four cubic feet per second, and this, being required to supply the usual consumption of the inhabitants, must be carefully preserved.

The entire quantity of water flowing down the river Lea in November 1833 (after supplying the New River), as measured at the King's Wear, above Waltham Abbey powder-mills, was found to be one hundred and ten cubic feet per second. As this was at the end of an unusually dry season, there will always be an ample supply for navigation and mill-power, as I do not recommend that any water be taken from the river below the town of Ware until after it has passed the Government establishment at Waltham Abbey.

By the contemplated arrangement, a division of the water would be adjusted, litigation prevented, and the metropolis supply, to a known extent, secured. But to meet the continually increasing demands of the inhabitants, and to compensate the loss of the Amwell spring (which has abandoned the New River, and now finds its way into the Lea), it is necessary to enable the company to provide a still greater quantity of water, and also to preserve it in greater purity; but to accomplish this, further Parliamentary authority is required.

1st. In order to obtain an additional quantity of pure water, without interfering with the contemplated arrangements, the company should be required to pump water from the river Lea some miles below the Government works at Waltham Abbey, towards which purpose they have purchased Tottenham Mill and thirty acres of land adjacent, and constructed reservoirs to the extent of thirty acres of water adjoining the New River at Newington, and adjacent to the site of Tottenham Mills; and there being also an old branch of the river Lea at present not in use, it should be transferred to the New River Company, who thereupon should be required to embank and enlarge it, to not less than twenty acres, and convert it into a settling reservoir, upon which the pumping engines should be placed.

In regard to the power of the engines to be constructed and employed, in order to guard against the effects of long-continued frosts, or unusual droughts, or being under the necessity of pumping from the river Thames, at Broken Wharf, the engines should be capable of raising two-thirds of the whole supply. This additional quantity being thrown

directly into the reservoirs at Newington, would have the advantage of being in the vicinity of the city, and create no further expense of conduit or other conveyance.

If the water is taken off at Tottenham, all the mills upon the river above that place, including the royal gunpowder-mills at Waltham Abbey, would still possess the entire water of the river, and if a quantity equal to two-thirds of what is supplied to the metropolis by the New River (viz. sixteen cubic feet per second) were drawn off by the engines at Tottenham, ninety-four cubic feet per second would still remain for the use of the mills below.

To guard against any injury that might arise to the navigation of the river Lea, in consequence of the powers herein recommended to be given to the New River Company, that company should be required to rebuild the lock at Tottenham Mill in a perfect manner, and keep it in repair; also to pay a fair and reasonable sum to the trustees of the River Lea Navigation, to be expended in deepening the river Lea where found necessary.

2d. The quantity of water requisite in aid of the New River being thus adjusted, it becomes of importance to preserve that stream from impurities while passing along a circuitous course of thirty-seven miles in length. I was at first sight disposed to recommend its being made more direct, by cutting off great bends, embanking valleys, &c.; but on survey, finding it of quite sufficient dimensions to convey all the water that the company had a right to take, also that the stream itself is, in effect, a very extensive reservoir, and that much expense would attend the proposed alterations, I consider it more advisable to adopt other means of improvement.

Where the New River commences at the Chadwell spring, the water is generally pure and transparent; but in passing thirty-seven miles of a populous vicinity without protection, it is unavoidably exposed to various impurities; the surface water from the uplands, sewages from the villages, cattle treading down the edges of the river banks, all combining to produce discoloration of the water, which is still more increased by the operations necessary to restore the banks, and, near the metropolis, by numerous persons bathing and creating other nuisances. The company should, therefore, be empowered and required to collect the water and sewage from the uplands and villages, and convey it under the New River to proper water-courses; and they should also be required to fence each side of the river in a proper manner so as to prevent the evils above mentioned, preserving a space between the fence and water of at least six feet in breadth, for the passage of workmen, making reasonable compensation to the proprietors of the adjoining lands.

The company should also have the power of summary punishment of trespassers, on conviction before magistrates; and the landowners and occupiers should be prevented from digging deep ditches at the bottom of the slopes, thereby weakening and endangering the banks.

3d. In regard to defraying the expense of the improvements here proposed, it appears that since the year 1828, the company have completed some very considerable works,

such as the Newington reservoirs, of thirty-eight acres, defraying the expense from their annual income; and I understand by their letter to the Treasury of July 1831, that they are able and willing to continue the improvements in the same manner, if Parliamentary powers were granted them.

4th. To ensure the improvements being properly executed, and the water duly distributed, the before-mentioned Parliamentary Commissioners should be empowered to examine into and decide any differences which may arise among the parties interested in the supply and purity of the water, which would prevent disputes, such as have already been productive of expensive litigation without satisfactory result.

THE EAST LONDON.

The East London Waterworks Company supply a very large and increasing district, being the North-eastern portion of the metropolis. The waterworks are situated at Old Ford, in the river Lea, just above Bow Bridge, and consist of a powerful apparatus of steam-engines and pumps, of the aggregate force of about three hundred horses, for raising and distributing water.

The water has hitherto been brought from the river Lea, at high water, into a large settling reservoir on the north side thereof, from whence it passes by pipes under the same river into smaller reservoirs, from which the pumps are supplied.

From this arrangement it is evident, that although the water taken from the reservoirs and distributed is in fact from the river Lea, yet it is the water of the Lea subjected to the contamination of the district through which it passes in and below the neighbourhood of Bow, and to the constant agitation of the tides in driving upwards towards the waterworks during the flood-tides; thus rendering it no better, as far as regards matter held in suspension, than the water of the Thames taken up in its passage through the metropolis.

After the Commissioners of Inquiry into the quantity and quality of water supplied to the metropolis had made their Report in 1828, the East London Waterworks Company took immediate steps to improve their water both in quantity and quality, by obtaining powers under an Act of Parliament, in the year 1829 [10 Geo. 4, cap. Local and Personal], to take water from the river Lea at or near Lea Bridge Mills, above the influence of the tide, and to convey it from thence to the works at Old Ford, by means of a new aqueduct (insulated from all other water), into settling reservoirs upwards of eighteen acres in extent, from which it passes into reservoirs, out of which the pumps are supplied as before stated.

These works are now on the eve of completion, and will be in action in the month of June of the present year, within the time allowed by the Act of Parliament.

In the prosecution of these improvements, the East London Waterworks Company have expended upwards of £.50,000, without having the power of imposing additional rates or charges on their customers; the maximum charges of housekeepers or private consumers being fixed by the Act.

Having assured myself, by a personal survey of the waterworks at Old Ford, and by an inspection of the new aqueduct and reservoirs now near completion, for taking water from the river Lea at the tail of the Lea Bridge Mills, that the above statements are correct, in which survey and inspection every facility was afforded by the directors of the company in furnishing information, and in the production of all documents deemed by me necessary for the investigation of the subject, I have no hesitation in stating, that, as far as the East London Waterworks are concerned, the improvements necessary for ensuring a better supply of pure water to their district have been anticipated by that company.

The only point upon which any question might arise is rather of a prospective nature, inasmuch as it relates to the sewage of the district on the west side of the river Lea, between Tottenham Mills and Lea Bridge Mills, which sewage is now discharged into the Lea; but should a greater number of buildings, or a town, grow up on that side of the river, it would then be advisable to carry the sewage of that district clear of the portion of the river above named, either by conveying it under the river at one or more points, or by connecting it with the Hackney sewage, which goes into the tideway of the river Lea below Old Ford lock. But this is a part of the subject which might with propriety come under the control of a general commission for the conservation of the water supplied to the metropolis.

Regarding the quantity of water now used, or likely to be required by this company, there is no doubt the river Lea possesses an abundance.

By the returns made to the Commissioners of Inquiry in 1828, it appears that the quantity then distributed by this company was eleven cubic feet per second in the aggregate; and making the due allowances for the extra quantity used in the warmest weather at twenty-five per cent. increase, adding moreover twenty-five per cent. for increase since that time, the amount would now be about sixteen cubic feet per second, and allowing another twenty-five per cent. for future demands, it gives a total of twenty cubic feet per second, as the greatest probable quantity required by this Company.

Now, it appears that the river Lea (as above stated in the Report on the New River) produces, in the times of shortest water, a surplus quantity of ninety-four cubic feet per second, after deducting what might probably be wanted by the New River Company in times of drought; and as the quantity required for the East London Company is not taken off until after passing through Lea Bridge Mills, and supplying all the wants of the navigation, there will still rèmain the above surplus of ninety-four cubic feet per second, for supplying the probable maximum demand of twenty cubic feet per second required by the East London Company.

Thomas Telford.

London, 17 February 1834.

Estimate,—NORTH SIDE OF THE RIVER THAMES.

ESTIMATE of the Expense of constructing a Line of Aqueduct and other Works requisite for conveying Water from the River *Verulam* (from *Bushey Mill* near *Watford*) to a Reservoir on *Primrose Hill*, for supplying with Pure Water Three of the Northern Districts of the Metropolis; including Purchase of Land, and Compensation to Mill-owners.

				£.	s.	d.
Small Reservoir and Works for regulating and drawing the supply from the River Verulam, and diverting the course of the River Colne - - - - - - - - - - - - -				11,500	-	-
Earthwork, in cutting, embanking and tunnelling on the line of Aqueduct from the River Verulam to Primrose Hill - - - - - - -	£.53,240	10	6			
Add 10 per cent. for contingencies - - - -	5,324	1	-			
				58,564	11	6
Iron Pipes for conveying the Water across the two Valleys of the River Brent - - - -	24,280	-	-			
Two small Bridges for ditto - - - -	1,400	-	-			
	25,680	-	-			
Add 10 per cent. for contingencies - - - -	2,568	-	-			
				28,248	-	
Brickwork in Aqueduct, with a double Watercourse, separated by a Footpath, from the Reservoir of the River Verulam to the Reservoir on Primrose Hill, being a distance (including the length of the above iron pipes) of 15 miles 490 yards - -	325,005	-	-			
Concreted Lime and Gravel in Foundation of Aqueduct - - - - - - - - -	13,937	4	-			
Culverts for Land-water - - - - - -	729	6	-			
	339,671	10	-			
Add 10 per cent. for contingencies -	33,967	3	-			
				373,638	13	-
Forming Reservoirs at Primrose Hill, including the necessary Works for dividing the supply of Water to the respective Water Companies or Districts - - - -				20,000	-	-
Main Pipes to connect the Reservoirs at Primrose Hill with the present Mains of the Grand Junction, West Middlesex and Chelsea Waterworks Companies - - - - - - - - - -				57,500	-	-
				549,451	4	6
Land on the line of Aqueduct - - - - - - - - -				12,200	-	-
Compensation to Mill-owners for Water taken from all the Mills between Bushey Mill and the River Thames - -				224,314	7	-
Total - - £.				785,965	11	6

ESTIMATE,—SOUTH SIDE OF THE RIVER THAMES.

ESTIMATE of the EXPENSE of constructing a Line of AQUEDUCT and other WORKS requisite for conveying Water from the River *Wandle*, at *Beddington Park*, to a Reservoir on *Clapham Common*, for supplying with Pure Water the Districts on the South Side of the Thames; including Purchase of Land, and Compensation to Mill-owners.

				£.	s.	d.
Machinery for regulating the quantity of Water taken from the River Wandle, including a Wear across the River, Sluices, &c. -				2,000	–	–
Earthwork, in cutting and embanking on the line of Aqueduct from the small Reservoir near Beddington Park, to the Reservoir on Clapham Common - - - - - - - -	£.16,488	5	–			
Add 10 per cent. for contingencies - - -	1,648	16	6			
				18,137	1	6
Brickwork in Aqueduct, with a double Water-course separated by a Footpath, from the small Reservoir near Beddington Park to Clapham Common (being 6 miles and 20 yards in length)	141,942	10	–			
Concreted Lime and Gravel in Foundations of Aqueduct - - - - - - - -	6,821	16	–			
Culverts for Land-water - - - - - -	948	12	–			
	149,712	18	–			
Add 10 per cent. for contingencies - - -	14,971	4	–			
				164,684	2	–
Forming Reservoirs on Clapham Common, including the necessary Works for dividing the supply of Water to the respective Water Companies or Districts - - - - - - - -	10,660	4	4			
Add 10 per cent. for contingencies - - -	1,066	–	5			
				11,726	4	9
Main Pipes to connect the Reservoirs on Clapham Common with the present Mains of the Lambeth, South London and Southwark Waterworks Companies respectively - - - - - - -				40,482	–	–
				236,979	8	3
Land on the line of Aqueduct - - - - - - - - -				4,800	–	–
Compensation to the Mill-owners for Water taken from all the Mills from Beddington Park to the River Thames - - - -				150,095	16	8
TOTAL - - £.				391,875	4	11
TOTAL for Three of the NORTHERN DISTRICTS of the Metropolis -				785,965	11	6
TOTAL for the DISTRICTS on the SOUTH SIDE of the River Thames				391,875	4	11
GRAND TOTAL - - - £.				1,177,840	16	5

APPENDIX (R. 3.)

FILTRATION of THAMES WATER at the CHELSEA WATERWORKS. Communicated by Mr. *James Simpson*, Resident Engineer.

THE process of filtering water on the extensive scale adopted at the Chelsea Waterworks being novel and interesting, as well as important, I am happy to communicate a general account of the success of the undertaking.

The managers of the Chelsea Works had determined to prosecute some plan for rendering the quality of the water supplied by them unobjectionable; and in the spring of 1826 I commenced experiments and inquiries upon the subject, so that when Dr. Roget, Mr. Brand and Mr. Telford, the Commissioners of Inquiry, visited the Works in the summer of 1828, they found the construction of filtering-works of some magnitude in an advanced state.

So little has been written on the subject of filtration of a practical nature, that the art of conducting the process upon a large scale was yet to be acquired, and improvements to be made upon the Works at Glasgow, Manchester and other places, where it appeared that instances of failure, as well as of success, had occurred. Preliminary experiments were indispensable to warrant expenditure of capital on such works, and several trials were accordingly made on superficies exceeding one thousand square feet, to ascertain the most approved principle, and the fitness of the various materials proposed to be employed. All the modifications of lateral and ascending filters proved disadvantageous, difficulties were encountered in preserving the various strata in their assigned position, according to the sizes of their component particles; and effectual cleansing could not be accomplished without the removal of the whole mass of the filtering medium. All devices by currents, re-action of water, and other means, also proved either inefficient, or inconvenient and expensive.

The mode of filtration adopted at the Chelsea Works is by descent, and the medium consists of fine and coarse river-sand, comminuted shells, and pebbles, and of small and large gravel. These materials are laid in a reservoir, their surface being disposed in ridges, which presents to the spectator an undulated appearance. The first experiments by descent failed; sufficient care had not been taken in the selection and separation of the materials. Explosions of condensed air in the tunnels for collecting the filtered water deranged the strata occasionally, and were obviated by air-drains. The filtration was, in one instance, stopped by the addition of fresh sand, without having previously removed the old sand, which should be applied as the upper stratum; although, in this case, the surface had been thoroughly cleansed previously, a film or puddle was formed on the original sand, and was sufficiently supported by the particles of sand to sustain five feet head of water, at first acting to impede, and eventually to stop the filtration. The process was greatly

improved by the introduction of the small shells, such as are usually found at Shellness, the flat surfaces of which overlap, and assist in the great desideratum of separating the sand from the gravel, and thus tending to preserve the free percolation in the lower strata, which is essential for ensuring filtration sufficiently rapid for waterwork purposes.

The strata on the site of the filtering-works, under the vegetable mould, consist of loam, sand and gravel, overlying the London clay to the depth of thirty feet. The sand and gravel contain powerful land-springs, and the masses of ferruginous conglomerate they pass through are so great, that the water is of an objectionable quality; therefore, in constructing the basin to receive the filtering materials, it was necessary to exclude all the land-water by clay and cement walling.

An excavation into the sand and gravel, of sufficient depth to admit of the water from the river flowing on to the filtering bed, would have involved too great an outlay; and this circumstance led to the construction of the basin, at a level which rendered pumping the water from the river unavoidable; but the consequent subsidence of the water, and the command of a constant flow to the filtering-bed, are advantages which result from the expedient of pumping; and the interest of the money saved has more than compensated for the annual expense. The filtering-bed covers an area of one acre, and there is an elevated reservoir of nearly the same size. Reference to the accompanying sketch will explain the construction of the filter. The lower stratum of gravel contains the tunnels for collecting the filtered water. They are built with cement-blocks, and partially open-jointed, two spaces of an inch and a half on the bed, and the heading-joint of each brick, being open. The fine gravel, pebbles and shells, and the coarse and fine sand, are laid upon the large gravel.

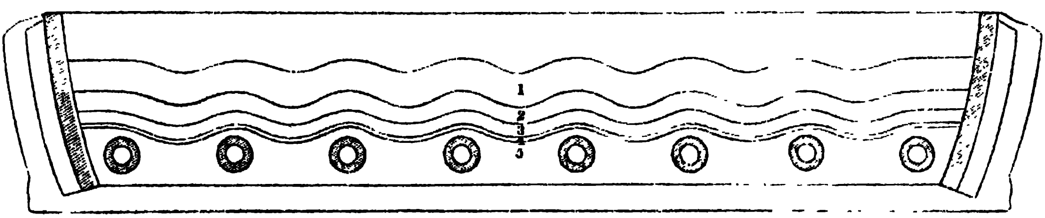
The water is let on to the filtering bed at nine places, and the ends of the pipes are fitted with curved boards to diffuse the currents of water, and prevent the surface of the sand from being disturbed. The interstices in the fine sand being more minute than the subjacent strata, it is found that the impurities are arrested near the surface, and it has not been necessary to remove more than one inch depth of the sand at any one time of cleansing. This work is effected by scraping the surface every fortnight, and upon a careful examination it has been discovered that the sediment penetrates to the depth of from six to nine inches, according to the state of the Thames water; the greatest penetration occurring during the prevalence of land floods in the river. Notwithstanding this, however, it is not necessary to remove more than the depth stated, which contains the grosser impurities, the remainder tending rather to improve filtration by rendering the interstices between the particles of sand still more minute. From these observations it must not be inferred that the process is merely a fine mode of straining, for something more is evidently effected; an appearance resembling fermentation being discernible when the water is in contact with the sand.

The quantity of water filtered is from three to four hundred thousand cubic feet daily, according to the demand. The undulated surface of the filtering-bed admits of parts of it being worked, and others drained; and it aids in cleansing, by admitting the grosser particles of the silt to slide down the ridges, and form a sediment easily manageable.

The removal of the sand is effected by lifting portions of the fine sand in succession, and placing fresh sand of the same description underneath them.

There is every reason to anticipate the various works in course of execution by the London water companies will add greatly to the health, comfort and convenience of the public, and as these works must of necessity be carried on by means of large capitals vested in fixed machinery, pipes, &c., for supplying ah article consumable only on the spot, and as such machinery, pipes, &c., are of little or no value for any other purpose, they should not be interfered with upon slight grounds, or the representations of designing persons. It ought to be borne in mind that the deprivation of the accustomed supply of water in any particular district of the metropolis would be a calamity from which most serious injury to the public might ensue, more especially if it occurred in the summer, or during the prevalence of epidemic fever; and although the present supply of water in the metropolis is susceptible of improvement, it is superior to that enjoyed by any other city in Europe; and in any event, the preservation of that supply is a most important object.

SECTION OF FILTERING BED.



REFERENCE.

1. Fine Sand.
2. Coarse Sand.
3. Pebbles and Shells.
4. Fine Gravel.
5. Large Gravel, containing the Brick Tunnels;— of which there are eleven under the Filter of the Chelsea Waterworks.

APPENDIX (S. 1.)

REPORT on DOVER HARBOUR, by *Thomas Telford*, Civil Engineer.

HAVING, on the 25th of January 1834, received the directions of his Grace the Duke of Wellington, to report upon the state of Dover Harbour, I proceeded to that place, and, on the 30th of January and the following day, I examined the harbour and the works connected with it, and conferred fully with the resident engineer, the harbour-master, and Sir Henry Oxenden.

The history and description of this harbour being well known, I shall confine my observations to its present state, and, referring generally to the plan of Dover Harbour, I shall proceed to communicate my opinion as to the most effectual means of rendering the harbour accessible at all times; for until this essential object is attained, attention to interior improvements might seem to be premature.

The tide here flows from the south-west, at the rate of three to four miles per hour; spring-tides rise sixteen or eighteen feet, neap-tides twelve or fourteen feet perpendicular. The prevailing winds are from the south-west; and a very unusual succession of violent gales from that quarter, during the last autumn and winter, produced an accumulation of beach, gravel or shingle on the bar, and in the entrance of the harbour, notwithstanding the utmost efforts of the harbour-master, and the application of all the means which have been devised for clearing away such obstructions.

It is to be understood that the beach, gravel or shingle, is constantly in motion from the south-west; so that although the channel was oftener than once nearly opened by sluicing, it was not regularly re-established until the 22d of January; and on the 30th I found it sufficiently good, although a considerable quantity of shingle still remained at the western pier-head, and on the north-east side of the entrance.

On the 31st of January (being the sixth day after full moon), the depth of water in the basin being eighteen feet, the culvert No. 3, in the pier-head, was opened by the harbour-master, at two minutes after ten o'clock A. M., and was closed at seven minutes after ten; and in these five minutes the shingle (five feet in height) opposite to this culvert was displaced.

The culvert No. 2 was then opened (10h. 8m. to 10h. 15m.), and in seven minutes the shingle opposed to it was entirely displaced.

The culvert No. 3 was then re-opened (10h. 10m. to 10h. 20m.), and in ten minutes (partly in conjunction with culvert No. 2) cleared away all the remaining shingle, the effect extending outward one hundred and fifty feet.

The sluice-gates in the cross-wall, between the harbour and the basin, were raised at the same time, that is, at two minutes after ten o'clock, and this current of water produced its full effect at the turn-water (north side of the harbour entrance) in the space of fourteen minutes, and continued in full force during thirty minutes, when daylight appeared under

the sluice-gates in the cross-wall, and in another half-hour the water lost its power. The length of the lower turn-water in use this day was sixty feet, the distance between the pier-heads being one hundred and ten feet.

From these experiments, I am led to conclude that if the effect of a back-water, extending over twenty acres behind the cross-wall, were exerted under more favourable circumstances, the harbour entrance might always be maintained; and if so, it is proper, in the first instance, to attempt an improvement in the effect of sluicing, especially as this would not preclude other and further improvements.

The existing defects in the sluicing are these: 1st. The culverts in the pier-head are too few in number, and of too great length; 2d. Nor are they fully supplied with water, the archway through which the back-water current reaches them not being adequately large; 3d. And, besides these defects, the distance from the sluices in the cross-wall to the harbour entrance is such that the current loses much of its force before it is brought to bear upon the external bar of the shingle.

For remedying of these defects, I recommend, 1st. That the culverts be shortened, and the iron lengths of tube thus obtained be applied in increasing the number of culverts; 2d. That a tunnel, thirty feet in diameter, be constructed in the body of the pier from the culverts quite to the wet-dock; 3d. And that a similar tunnel be made from the said wet-dock to the basin, thereby also communicating at pleasure with the inner Pent.

All this would give the command of more than twenty acres of back-water, applicable with undiminished force through the culverts in the pier-head, thus bearing directly upon the bar; while the seven acres additional of harbour back-water will be directed on the same object by means of the turn-waters on the north side of the harbour entrance.

After the additional culverts are completed, an apron, or granite pavement, thirty feet in breadth, should be placed around the pier-head, so as to prevent the violence of the culvert discharge from scooping pits in the chalk, which are receptacles of shingle; whereas the proposed pavement would facilitate the removal of shingle wherever collected on it.

But as granite is expensive, and Portland stone unfit for harbour masonry, I recommend in preference to either, for general purposes, but not for the above-described pavement, the Bramley-Fell stone from Yorkshire. This is of durable quality for such purposes, and was found preferable to any other at the St. Katharine's Dock.

As the harbour entrance is of primary importance, I recommend that all operations in the interior do forthwith cease until this is secured, and that the materials intended for other purposes be employed in the more urgent and decisive operations herein recommended.

The expense has been estimated, with as much accuracy as the nature of the wall admits, at £.20,000.

During the present year, 1834, this communication may be accomplished, and by the additional supply of back-water acting with undiminished force upon the bar, in the ensuing winter season, by means of the present tunnels, the effect would, I expect, be very considerable.

During the year 1835, the additional culverts in the pier-head, the apron or advanced pavement, and the tunnel between them and the wet-dock, may be accomplished; and the expenditure of £.20,000 might thus be equally divided between the two years 1834 and 1835.

10 February 1834. *Thomas Telford.*

Mem :—It is high-water in the harbour at full and change, about 11 h. 15 m. The flood-tide runs five hours; the ebb, more than seven hours. About one hour and three quarters before high-water *by the shore*, the stream outside begins to make to the eastward; and a counter-current (forty or fifty fathoms wide) sets to the westward, across the harbour-mouth. This requires attention, lest it should drive a vessel against the western pier-head. The best time for entering the harbour is about an hour and a half before high-water, when the stream is slack. On the western pier-head are two flag-staves, on the largest of which a red flag is kept flying by day, and a red light is shown on each flag-staff at night, while there is more than ten feet water in the harbour entrance. Spring-tides rise nineteen feet; neap-tides, fourteen feet.

John Scott Tucker.—1833.

APPENDIX (S. 2.)

PROGRESS of the IMPROVEMENT of DOVER HARBOUR ENTRANCE.

Communicated by *James Walker, Esq.*, P.I.C.E.

No harbour, and scarcely any engineering subject of the same apparent facility at the first view of it, has caused more difference of opinion, or more difficulty in the mode of treating it, than Dover Harbour, while its great advantage, as being the nearest port to France, has rendered the improvement of the harbour a matter of great and almost national importance. One of the great evils is the accumulation of shingle in front of the entrance; this is brought up from the west by the prevailing southerly and westerly winds, and lodged directly at the entrance to such an extent and height, as sometimes to completely block up the entrance for several days together, particularly during winter, and in rough weather, when the harbour is of the greatest consequence.

The management of the harbour is under the Lord Warden of the Cinque Ports (at present the Duke of Wellington), the Lieutenant Governor of Dover Castle (at present R. H. Jenkinson, Esq.), and a body of the most influential gentlemen of the county; and these have called in aid the professional assistance of the most eminent engineers of their day; at various times, Smeaton, Gurney, Huddart, Ralph Walker, Rennie, who have all reported their opinion, and under whose advice various works were done for the improvement of the harbour. The outer harbour is divided from the basin and Pent by a cross-wall, in which there are gates for the passage of vessels. These gates, being shut at high-water,* retain in the basin and Pent nineteen acres of water, and at low water the large sluices

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* The average rise of a spring-tide on harbour-index is - - - - - -	17 feet.
And that of a neap-tide - - - - - - - - - - - - -	13 feet.

which are built in the cross-wall being opened, the water is discharged with great force through the sluices, and runs with considerable velocity through the outer harbour, to the entrance where the stream is narrowed, and directed by turn-waters, movable as occasion may require, against the bar; but the main power of impulse was lost after the immediate discharge from the sluices. The above method was frequently found insufficient to clear the harbour entrance; and it was sometimes necessary to have one hundred men, with horses, trying to make a breach through the accumulated shingle without effect. The delay to trade and the danger may be easily supposed.

Mr. Moon, the ingenious harbour-master and superintendent, about the beginning of the present century, appears to have suggested the plan of bringing the water from the basin through culverts, placed behind the walls, so as to discharge it directly upon the bar, in front of the south pier; and Mr. Ralph Walker being consulted, approved the plan, and recommended iron in preference to brick or stone for the purpose. Accordingly, a pipe five feet diameter was laid from the basin to the wet-dock, and thence was carried through a culvert to a small reservoir, about two hundred and thirty feet from the pier-head; and from this reservoir, three pipes, two of seven feet diameter, and one of five feet, with sluices, branched off. The effect of this was found to be good; the water being discharged, with a considerable head, directly upon the bar, cut through it in a way to which the former plan was unequal. Still the evil, but in a less degree, existed; the five-feet pipe being insufficient to supply the larger outlet pipes, the power of discharge was lessened, and confined in its operation; and the complaints against the harbour were as loud as ever.

Mr. Moon died in 1832, and was succeeded by Mr. Fordham, as resident engineer, and Mr. Iron, as harbour-master; their attention was given to the subject, and in 1833, they proposed the plan of substituting a large brick tunnel for the five-feet pipe, and of enlarging the reservoir, with an additional number of sluices; a plan for increasing the sluicing power, the necessity for which was increased by the harbour being shut up for several days in the month of December 1833, and in the early part of January 1834. The then state of the harbour, and the object of the application to Mr. Telford, will be better understood by the letter of the Lord Warden (the Duke of Wellington) to him, written from Strathfieldsaye, on the 25th January 1834.

'Sir,

'You will have heard reports of the inconveniences experienced at Dover, in consequence of the impediments to the entrance of the harbour, by the constantly repeated collection of shingle upon the bar.

'These inconveniences, although greatly exaggerated, certainly exist to a certain degree at all times; they have been removed up to this time by the skilful application of a very moderate quantity of back-water, through culverts, and by means of sluices; but the gales from the southward and westward having prevailed to a greater degree than usual during this autumn and winter, and repeatedly for several days and nights successively, it has been found impossible to clear away the beach so fast, and as

'frequently, as it is collected; the entrance of the harbour, therefore, has been at times 'entirely closed, notwithstanding the vigilant attention of the harbour-master, and the 'constant application of all the means at his disposal to remove the beach; but I must 'add, that this inconvenience does not appear, by the official reports, to have occurred 'so frequently as has been publicly stated.

'It is desirable, however, to satisfy the public upon this subject; and I am anxious 'that you should take the trouble of going to Dover, and that, after examining the 'existing works for the construction and maintenance of the harbour, and conversing 'with the engineer employed there by the Lord Warden and Court of Assistants, and the 'harbour-master, you should report your opinion, whether any other and what descrip-'tion of works ought to be constructed for the purposes of a harbour at Dover; at what 'expense; and, if you should think the works now in existence are sufficient for the 'purpose, whether any and what additional means of operation could be given to them 'to render them more efficient.

'I think it proper to send you reports on this same subject, received some years ago by 'my predecessors in office.

'You will see that they are contradictory; and that the Lord Warden and Court of 'Assistants were finally advised to adopt the system which is now being carried into 'execution. But you will judge from the whole on the spot, after hearing the engineer, 'the harbour-master, the pilots and other persons, and gentlemen most capable to give 'you information, what it is fit that you should recommend to be done.

'I have the honour to be, &c. &c.

'To Thomas Telford, Esq. (signed) '*Wellington.*'
'Civil Engineer,
'Abingdon-street, Westminster.'

In consequence of this, Mr. Telford visited Dover, and afterwards arranged with Mr. Fordham the plans; entered into contracts with Mr. Burge for some of the works, and superintended the same until the time of his death.

The plan consists of the substitution of a brick-tunnel, thirty feet wide and sixteen feet high, in place of the five-feet pipe; from the basin into a new and larger reservoir, from which eight pipes radiate with sluices, so as to discharge upon an apron in front of the pier-head. At the time of Mr. Telford's death the greater part of the brick-tunnels was made; part of the excavation for the reservoir-dam, and a small part of the wall, built; but none of the drawings prepared, or work done, towards the sluices or machinery.

The works are now (March 1838) completed under contracts (by Mr. M'Intosh, and by Messrs. Hunter and English for the machinery, under Messrs. Walker and Burges, the engineers, and Mr. Howkins, resident engineer), without any alterations to affect materially the design; three of the new sluices were opened on 25th October 1837, and the success has quite equalled the expectation, as may be seen by the following letter from the present harbour-master to Mr. Walker.

'Sir, Dover, 11 February 1838.

'I beg leave to state that the entrance into Dover Harbour, during this winter, has 'been clearer from bar than any winter since I have been in office. We have had no 'obstruction to vessels coming in or going out, and the passage has been kept open. 'Many valuable vessels have taken shelter here during the easterly gales, and several 'remain until the ice breaks up on the opposite coast. The prevailing easterly winds 'have had no bad effect on the harbour. We have now a safe channel into the harbour, 'sufficient to admit any ship whose size is calculated to use the port.

'I do not hesitate to state, that had it not been for the new sluices, though they cannot 'be put fully into operation, we must have had at times the harbour completely blocked 'up in the early part of the winter, from the effect of the westerly and south-west gales 'bringing a great quantity of beach along the shore, and not having the means to remove 'it; and I have no doubt but I shall at all times (with the exception of any extraor-'dinary cases) be able to keep a good channel for ships to enter the harbour; but it being 'a bar-harbour, the alteration of the winds must at times alter the channel into the 'harbour.

'I am, Sir, &c. &c. &c.

'To James Walker, Esq. 'Civil Engineer, &c. &c. &c.'

'*John Iron*, 'Harbour Master.'

Mr. Walker's last report to the Duke of Wellington is to the same purport, and includes suggestions as to the further improvement and enlargement of the harbour and its entrance.

In closing this short outline, it is proper to notice the personal attention and frequent attendance given by the Duke of Wellington during the progress of the works; also by Mr. Jenkinson and by Sir Henry Oxenden; the latter, not only since the commencement of the present improvement, but for half a century previously, as an active Commissioner in the care of Dover Harbour.

APPENDIX (T.)

INSTITUTION of CIVIL ENGINEERS—25 January 1820.

Mr. *Palmer* in the Chair.

MOVED by Mr. *Provis*, and seconded by Mr. *Jones*,—

That in order to give effect to the principle of the institution, and to render its advantages more general, both to the members and the country at large, it is expedient to extend its provisions by the election of a President, whose extensive practice as a civil engineer has gained him the first-rate celebrity; and of persons as honorary members or associates, who, by their indefatigable exertions in the cause of science, have rendered themselves respected for their learning.

Resolved, That a respectful communication be made to Thomas Telford, Esq., F.R.S.E., Civil Engineer, requesting him to patronize this institution, by taking on himself the office of President to the same.

Resolved, That a respectful communication be framed as an invitation to gentlemen of reputed learning (whose names shall from time to time be proposed according to the rules of the institution) to become honorary members, and the same shall be retained as a form to be used, and none other, without the consent of the institution, and that such honorary members shall not be expected to contribute pecuniarily to the institution.

MOVED by Mr. *Collinge,* seconded by Mr. *Field,*—

That the secretary be requested to prepare an invitation to Mr. Telford to become President to this institution; and also a form of invitation for honorary members.

EXTRACT from the INAUGURAL ADDRESS of Mr. *Telford,* after accepting the above Invitation.—(21 March 1821.)

'IT is my duty, as President,' (he said, after a few words of preface,) 'to offer some remarks on the nature of the institution and its probable results; they shall only be few and short, it being, I trust, sufficiently apparent that the principles of the institution rest more upon practical efforts and unceasing perseverance than upon any ill-judged attempts at eloquence.

'Having had no share in, or even knowledge of, the original formation of this institution, I can speak with more freedom of its merits. It has, in truth, like other valuable establishments of our happy country, arisen from the wants of its society, and, being the result of its present state, promises to be both useful and lasting.

'From a view of the topography and statistics of this country, it is quite evident that civil engineering has increased to an extent and importance which urgently demand such a separate establishment as you, its earliest members, have so judiciously planned, and by meritorious perseverance brought to its present state.

'I have carefully perused the Rules and Orders, which have been prepared with much attention, and I think they are now sufficiently matured to be a guide and guard for the conduct and welfare of the institution. Judicious regulations are absolutely necessary in all societies, but I trust that in this, the good sense of the members will always prove that manners and moral feeling are superior to written laws, and will render my duty as President both easy and pleasant.

'In foreign countries similar establishments are instituted by government, and their members and proceedings are under its control; but here, a different course being adopted, it becomes incumbent on each individual member to feel that the very existence and prosperity of the institution depend in no small degree on his personal conduct and exertions; and the merely mentioning the circumstance will, I am convinced, be sufficient to command the best efforts of the present and future members, always keeping in mind that talents and respectability are preferable to numbers, and that from too easy and promiscuous admission, unavoidable, and not unfrequently incurable, inconveniences perplex most societies.'

APPENDIX (U.)

ESKDALE. A DESCRIPTIVE POEM.

By *Thomas Telford.*

ESKDALE, or the Dale by the river Esk, lies about the centre of that district of the border of Scotland, which is thus described by Dr. Percy in his Reliques of Antient Poetry: 'Most of the finest old Scotch songs have the scene laid within twenty miles of 'England, which is indeed all poetic ground, green hills, remains of woods, clear brooks. 'The pastoral scenes remain: of the rude chivalry of former ages, happily nothing 'remains but the ruins of the castles.'

The following little Poem, descriptive of the scenery of this country, was written in early youth, when the situation of the Author gave him little opportunity of being acquainted with English Poetry. It was then published at the request of some friends, who had the kindness to take an interest in it, from the circumstances in which it was composed.

As it is now reprinted at their desire, the Author has not thought himself at liberty to make any material alterations in it, except by the addition of a few lines in the conclusion.

Thomas Telford.

THY pleasant banks, O ESK! and shady groves,
The seat of innocence and simple loves,
Demand my lay!—may thy own Muse descend,
And o'er her much-loved scenes my feeble steps attend!—

Here, lofty hills in varied prospect rise,
Whose airy summits mingle with the skies,
Round whose green brows, and by the aged thorn,
The early Shepherd seeks his flock at morn;
Or, on the sunny side at noontide laid,
Sees his white charge in gay profusion spread,
While round the KNOW*, beneath th' inspiring Sun,
His bounding lambs their playful races run.

Deep wind the green sequester'd glens below,
Where murmuring streams among the alders flow,
Where flowery meadows down their margins spread,
And the brown hamlet lifts its humble head.

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* Knoll, a little green hill.

There, round his little fields, the Peasant strays,
And sees his flock along the mountain graze;
And, while the gale breathes o'er his ripening grain,
And soft repeats his upland Shepherd's strain,
And western Suns with mellow radiance play,
And gild his straw-roof'd cottage with their ray,
Feels Nature's love his throbbing heart employ,
Nor envies towns their artificial joy.

At distance, rocks in glittering splendor stand,
When first the Sun salutes the joyous land;
But when he gains the summit of the skies,
And o'er our heads in wanton triumph flies,
The fragrant groves afford a chequer'd shade
Of various hues, by Nature's hand array'd.
Here, clustering thick, the oaks their branches spread,
And there the lofty ash-tree rears his head;
The cheerful birch amid the grove prevails,
And wafts her odours on refreshing gales:
These, thick embowering, form a cool retreat,
Where heats in vain and angry tempests beat;
Or scattering wide, an opening glade appears,
Where elves and fairies play'd in former years.
These gentle beings sought green haunts of yore,
But all their wanton feats are now no more.

Where, far above, the closing vale recedes,
And all the soften'd landscape sinks in shades,
Confined by meeting hills o'erhung with woods,
The foaming stream precipitates his floods:
Thence, slowly winding through the fertile plain,
He onward comes, till hills confine again;
Now lost, now seen, he rolls his gathering train;
Till, sunk in woods profound, he seeks the western main.

Not thus in ages past; one forest wild,
Nor the green hill, nor pleasant valley smiled;
But rugged glens and pathless woods were seen,
Where beasts of prey howl'd round their bloody den.

Rude BRITAIN then (the polish'd arts unknown),
To barbarous rage and headlong fury prone,
Prey'd on herself; to hunt the mountain boar,
To hear the hills resound the savage roar,

To bend the bow, and run the rapid race,
Or foremost brave the tide in doubtful chace,
Was their delight: the Celtic feast succeeds,
The shell went round and songs of warlike deeds:
Fired by the sound, the hunters rush'd to fight,
Devoid of fear their hearts, their steps unknown to flight.
Thus lived the ancient heroes of the North,
And thus they fought when FINGAL led them forth;
When, Prince of Scottish Bards, great OSSIAN sung,
While to his voice the echoing MORVEN rung.

And thus in later days, when English arms
Shook thy deep woods with wars untired alarms,
On the dark rock the BORDER CASTLE rose,
And frown'd defiance on its Southern foes.
Around the chief the ready vassals throng,
And the hall echoed to the warlike song.
Forth to the field, when rose the opening day,
March'd the stern bands, and mix'd in bloody fray;
Or, silent stealing by the moon-beam cold,
Swept o'er the dawn the riches of the fold.
Alternate plunder mark'd the varying years;
Each evening brought its triumphs or its tears:
While Power and Rapine grew from sire to son,
And the song sanction'd what the sword had won.

Awaked at length, BRITANNIA rear'd her head,
And feudal Power and Superstition fled.
One equal law* the hostile nations bound,
And Peace diffused her unknown joys around;
Commerce at last her daring sails unfurl'd,
And BRITAIN rose the envy of the world.

As o'er the land improving arts extend,
Rejoicing ESKDALE feels their powers descend.
Stript of her cumbrous loads, her mountains rise,
While at their feet the peopled valley lies:
The less'ning woods, that dark and dismal frown'd,
Now spread their shelter, not their gloom, around;
And where the boggy fen neglected lay,
Smiles the white cottage and the village gay.

* The Union.

Her sons, inspired by love of arts and arms,
Whose glowing bosom patriot virtue warms,
Around the world the much-loved name convey,
From western oceans to the rising day.
None bolder rise in BRITAIN's sacred cause;
None wiser in the senate form her laws.
E'en now, she spreads her JOHNSTONE's* sounding name,
And points to PASLEYS† in the rolls of fame.
These on thy banks, O ESK! were wont to stray,
Smiling in youthful prime and infant play;
Oft through thy woods they've ranged, unknown to care,
And pull'd the hazel-nuts and roses fair;
Or, wandering bold thy moss-clad rocks among,
Heard Echo answer to their joyous song.

As the young lion near his native den,
By depth of woods removed from haunts of men,
Around the rustling bush, or spreading tree,
Plays harmless long in wanton sport and glee,
Till growing strength awakes his latent fire,
Then roams abroad, and emulates his sire:
Thus in their breasts they felt the generous flame,
And glowing sigh'd for an immortal name.
While some the field and warlike honours charm,
Paternal deeds their throbbing bosoms warm;
O'er Ocean's awful realm they boldly sweep,
And hurl the British thunders o'er the deep.
Others, intent by arts their name to raise,
In distant regions‡ seek the meed of praise;
In other climes display their native fire,
And prove the virtues which thy scenes inspire.

The Muses, too, from THAMES' green margin came,
And on thy banks have nursed young sons of Fame;
With care they form'd thy ARMSTRONG's§ rising soul,
And bade his name resound from pole to pole;

* The Westerhall family, which is now represented by Sir William Pulteney, Bart., who is well known in the political world, and for the very active part which he takes in promoting every plan for the improvement of the country.

† The Pasleys of Craig, one of whom, Sir Thomas Pasley, Bart., Rear Admiral of the Red, will long be dear to every Briton for his gallant services in the actions with the French fleet on the 1st of June 1794, when his spirited exertions contributed in an eminent degree to the signal victory gained by the British fleet.

‡ Gilbert Pasley, for many years Surgeon-General to the East India Company at Madras.

Dr. Ralph Irving, a man of very superior talents, author of several valuable medical essays, and much distinguished in India by the late Sir William Jones.

§ Dr. Armstrong, author of that beautiful poem on the Art of preserving Health.

Resolved their fav'rite POPE should live again,
They gave thy MICKLE* all his tuneful strain,
Taught him to roll the tide of verse along,
And GAMA's deeds immortalize in song.
Ah! if thy charms would rouse his filial flame
To bid them live with his unfading name,
Then, though Time roll'd his circling years away,
Or War's dread havock made thy vales his prey,
Thy bright'ning fame in distant realms would shine
And WINDSOR's rural beauties yield to thine!

Ah! vain the wish! and vain the Muse's tear!
Thy MICKLE sleeps on his untimely bier—
On other scenes his dying eyelids closed—
In other vales his hallow'd dust's reposed!—
Genius and Friendship weep around his urn,
And all thy hills, and all their echoes, mourn.

Yet still one voice, while fond remembrance stays,
One feeble voice, shall celebrate thy praise;
Shall tell thy sons that, wheresoe'er they roam,
The hermit Peace hath built her cell at home;
Tell them, Ambition's wreath, and Fortune's gain,
But ill supply the pleasures of the plain;
Teach their young hearts thy simple charms to prize,
To love their native hills, and bless their native skies.

APPENDIX (V.)

Mr. *Telford*'s SECRET LIBERALITY.

EXTRACT of a LETTER from Mr. *George May* to Mr. *Rickman*, dated Inverness, 20 February 1838.

I AM aware that it would be utterly presumptuous in me to hazard any remarks on the general lineaments of Mr. Telford's character and disposition, respecting which your long and familiar intercourse with him entitles you to speak more confidently and authoritatively than any other person. Nevertheless, there is one trait to which I may refer, because from it the observation of his most intimate friends was carefully excluded, but which, from the position I occupied, I could not escape from occasionally witnessing; I mean his active

* William Julius Mickle, translator of the Lusiad.

benevolence in every case of misfortune or distress that was presented to him. Numerous applications of this nature were incessantly made to him; and while in many cases the most liberal aid was afforded, I never knew an instance of unkind rejection. The possession of any talent, literary, scientific or mechanical, I always observed was an irresistible passport to his bounty; although he seldom failed to accompany it with a rebuke, more or less gentle, yet conveyed in his own peculiarly effective manner, on the indiscretion and irregularities which too often led to the application. But even without any claim of this sort, numbers, particularly of his poor countrymen, experienced the frequent effects of his benevolent aid; for, among other seemingly latent qualities, he ever retained that strong attachment to the land of his birth which is said to be peculiarly characteristic of the natives of the northern division of Britain.

APPENDIX (W.)

LETTER addressed to Mr. *Telford* from the Russian Government, inscribed on a Brilliant Diamond Ring.

Sir,

IN a letter dated 14th—26th February 1808, which I received the 20th of last October from His Excellency Count Raumantzoff, Minister of Foreign Affairs, Minister of Commerce and Chief Director of the Board of Inland Navigation in Russia, His Excellency informs me that he has made known to his Imperial Majesty the Emperor of all the Russias, the kind attention you have manifested towards our studies on Civil Engineering; His Imperial Majesty, being sensible of it, has been pleased to present you with a brilliant ring as a testimony of his high satisfaction, and Count Raumantzoff, in forwarding the same, directs me to transmit it to you in the name of His Imperial Majesty.

In fulfilling this pleasing duty, I have the honour to remain, with the greatest esteem and regard,

Sir,

Your most obedient and humble Servant,

Leon de Waxell,
Member of the Board of Inland
Navigation in Russia.

London,
No. 1, George-street, Portman Square,
the 9th November 1808.

APPENDIX (X.)

COPY of the WILL of *Thomas Telford.*

I, THOMAS TELFORD, of Abingdon Street, Westminster, being desirous of testifying my sense of the good-will and kindness which has subsisted between myself and those with whom I have been most intimately connected through life, and being of sound mind, this 9th day of June in the year of our Lord 1834, do make this my last Will and Testament; that is to say, It is my desire, that after my just debts are paid, and the expense of a decent funeral, in a place to be selected by my Executors, that the remainder of my property shall be disposed of in the following manner:—

The expense of the publication, describing the works in which I have been engaged from my earliest years, to be defrayed under the direction of my Executors.

		£.	s.	d.
To each of the children of the Rev. Archibald Alison of Edinburgh - - - - - - -	Two hundred pounds	800	–	–
To James Hope, W.S., Edinburgh - - -	Five hundred pounds	500	–	–
To John Hope, his son, W. S. - - - -	Five hundred pounds	500	–	–
To John Rickman, of the House of Commons -	Five hundred pounds	500	–	–
To William Charles Rickman, his son - - -	Five hundred pounds	500	–	–
To Alexander Milne, of the Land Revenue Office -	Five hundred pounds	500	–	–
To Colonel Pasley, of the Royal Engineers, Chatham	Five hundred poun	500	–	–
To Robert Southey, Poet Laureate - - -	Five hundred pounds	500	–	–
To Thomas Campbell, Poet - - - - - -	Five hundred pound	500	–	–
To Thomas Stanton, Ellesmere, formerly my clerk	Four hundred pounds	400	–	–
To William A. Provis - - - ditto -	Four hundred pound	400	–	–
To Joseph Mitchell, of Inverness - ditto -	Four hundred pound	400	–	–
To George May, of Inverness - ditto -	Four hundred pounds	400	–	–
To Alexander Gibb, of Aberdeen - ditto -	Four hundred pounds	400	–	–
To William Anderson, Paddington ditto -	Four hundred pounds	400	–	–
To John Pollock, Road Surveyor, my deputy -	Four hundred pounds	400	–	–
To John Macneil, - ditto - ditto -	Four hundred pounds	400	–	–
To George Turnbull, my present clerk - - -	Four hundred pounds	400	–	–
To the widow and family of the late John Mitchell, of Inverness, my deputy on Roads - - -	Four hundred pounds	400	–	–
To the widow of Thomas Denson, ditto ditto on Canals - - - - - - - -	Four hundred pounds	400	–	–
To Alexander Easton, - - ditto ditto -	Four hundred pounds	400	–	–
To Sir Henry Parnell, Bart. - - - -	Four hundred pounds	400	–	–
To Dugald Bannatine, Glasgow - - - -	Two hundred pounds	200	–	–
To Dr. Cleland, - ditto - - - -	Two hundred pounds	200	–	–
To James Jardine, civil engineer, Edinburgh - -	Two hundred pounds	200	–	–
To William Playfair, architect, ditto - -	Two hundred pounds	200	–	–

		£.	s.	d.
To W. G. Adam, barrister, London - - -	Two hundred pounds	200	–	–
To Tycho Wing, Thorney Abbey - - - -	Two hundred pounds	200	–	–
To Thomas Eyre Lee, Birmingham - - -	Two hundred pounds	200	–	–
To John Freeth, - ditto - - - -	Two hundred pounds	200	–	–
To George Nicholls, Branch Bank, Birmingham	Two hundred pounds	200	–	–
To James Walker, civil engineer, London -	Two hundred pounds	200	–	–
To William Cubitt, ditto ditto -	Two hundred pounds	200	–	–
To Edmund Turrell, engraver ditto -	Two hundred pounds	200	–	–
To Thomas Casebourne, civil engineer - -	Two hundred pounds	200	–	–
To the President for the time being of the Civil Engineer's Institution, in trust, the interest to be expended in annual premiums under the direction of the Council - - - - - - - -	Two thousand pounds	2,000	–	–
To the Minister of the parish of Westerkirk, in the county of Dumfries, in trust for the Parish Library, the interest to be annually expended in the purchase of books, under the direction of the Committee of Management for the time being - -	One thousand pounds	1,000	–	–
To the Minister of the parish of Langholm, in trust for the Library, the interest to be annually expended in the purchase of books, under the direction of the Committee for the time being - - -	One thousand pounds	1,000	–	–

If the property should be more or less than the before-mentioned amounts, the appropriation to be increased or diminished accordingly; and if the persons herein named shall die before me, and I do not alter my Will, then I direct that the sums opposite their names, or in that proportion, shall be paid to their heirs after my decease.

All my scientific books, book-cases, prints, and such drawings as my Executors shall consider suitable, are to be delivered to the President of the Civil Engineer Institution, for its use and benefit, on condition that all those articles, as well as the books, prints and drawings already presented by me, shall, in case of the said Institution being discontinued, be delivered to the Royal Society, Edinburgh, for its use.

All the household furniture to be sold, and its value applied to the before-mentioned purposes. My clerk and servants at the time of my decease each to have six months' wages extra, and my man-servant to have my wearing apparel. My Executors to divide amongst themselves, or destroy, all such books, prints, drawings and papers as are not in their opinion suitable for the before-mentioned Institution. And I hereby appoint the before-mentioned John Rickman, James Hope and Alexander Milne, to be the Executors of this my last Will and Testament, and which I substitute in place of all others before the date hereof.

(signed) *Thomas Telford.*

APPENDIX (Y. 1.)

Mr. *Telford's* POCKET MEMORANDUM BOOK; its Contents arranged in Classes.

MEASURES.

1. FRENCH MEASURES.

Parisian foot to English foot, as 1,068 to 1,000, or as 114 to 107, nearly.

Toise, equal to 76·726 English inches.

Metre, ditto - 39·371 ditto.

Muid, 8 French cubic feet, or 8·544 English.

Pouce, or inch of water, produces 72 muids in 24 hours.

2. RUSSIAN WERST:

Equal to - - - - 3,500 English feet.

3. ROMAN MEASURE OF LENGTH.

Barleycorns in breadth	- -	1 doigt.
4 doigts (3 inches)	- -	1 palm.
4 palms	- - - - - - -	1 foot.
5 feet	- - - - - - - -	1 geometrical step.
125 geometrical steps	- -	1 stade.
8 stades	- - - - - -	1 milliare.
2 milliares	- - - - -	1 French league.

4. LAND MEASURE.

Gunter's chain, 4 poles of 66 feet. It consists of 100 links, each link $\frac{66}{100}$ part of a foot, $\frac{22}{100}$ of a yard, or 7·92 inches.

An acre is 10 square chains, or 10 chains long by 1 broad;

Or 220 yards × 22=4,840 square yards;

Or in links, 1,000 × 100=100,000 square links;

Or an acre consists of 4 roods, each rood of 40 perches or square links.

When the content is found in square links, cut off five figures on the right hand for decimals; the remainder is acres.

These decimals, multiplied by 4, gives roods, and the decimals of these, by 40, gives perches.

5. MEASURE.

Winchester bushels contain 8 Winchester gallons of 272½ cubic inches, equal to 2,180 cubic inches for the bushel; 8 of these bushels are 1 quarter.

Barrel of ale, London - - - 32 gallons.
Ale gallon contains - - - - 282 cubic inches.
Wine gallon - - - - - - - 231 ditto.
In all other places in England, excepting London, the barrel, both of ale and beer, contains } 34 gallons.
The beer barrel in London - - 36 gallons.
The Scotch pint contains - - 103·5 cubic inches.
Wheat firlot contains - - - 21 pints.

Imperial gallon, 277·274 cubic inches, equal to 10 pounds of distilled water, at the temperature of 54½°, barometer, 30 inches; 100 gallons, 16 cubic feet.

6. French Weights.

Killogramme - - - - - - =22·766 grains.
By Barlow, =2·2046 English lbs. or - - - - - = 3·28 lbs. Avoir.
or - - - - - = 2·1133 lbs. Troy.
or - - - - - =15·444 grs. ditto.

Quintal of Paris, in the old system, 123 lbs.
English quintal, 112 lbs.

7. French Money.

		Silver.	Gold.
France -	Livre Tournois - - -	9·54 -	9·38
	Franc, new system - -	9·70 -	9·52

The above determined when gold is £. 3. 7*s*. 10½*d*. and silver 5*s*. 2*d*. per oz., being Mint price.

Livre, equal to 20 sous or sols.
Sol - = - 12 deniers, or French penny.

8. Specific Gravity.

	oz.		oz.
Fine Gold - -	19·648	Brick - -	2·400
Standard Gold -	18·888	Earth - -	1·984
Lead - -	11·340	Chalk - -	1·793
Fine Silver -	11·092	Sand - -	1·520
Standard ditto -	10·536	Common Water	1·000
Copper - -	9·000	Dry Ash - -	·838
Ditto halfpence	8·915	„ Elm - -	·801
Cast Brass -	8·100	„ Oak - -	·800
Steel - -	7·850	„ Beech -	·700
Iron - - -	7·644	„ Fir - -	·580
Tin - - -	7·320	New-fallen Snow	·086
Cast-Iron - -	7·000	Ice - - -	·908?
Marble - -	2·707	Common Air -	·0012
Common Stone -	2·500		

9. Weight of Bodies.

Cubic foot.	lb. Avoir.	Cubic foot.	lb. Avoir.
Gold - - -	—	Free-stone -	156
Silver - -	—	Chalk - -	112
Lead - -	708	Brick - -	125
Copper - -	562	Clay - -	107
Cast Brass -	506	Sand - - -	95
Tin ditto - -	522	River Water -	62½
Steel - -	490	Sea ditto - -	64½
Iron -	478	Earth - -	124
Ditto, Capt. Emerson	437½	Ice - - -	57
		Dry Ash - -	52½
Ditto, Hutton	464	„ Elm - -	50
Ditto, Coal B. del.	432	„ Oak - -	50
		„ Birch - -	44
Tin - - -	457½	„ Walnut -	40½
Marble - -	169	„ Cedar - -	38
Pebble-stone -	169	„ Fir - -	36

' Sic

River Water weighs 62·5 lbs. Avoirdupois, at temperature 56½ deg. Fahrenheit.

10. Earth's Curvature.

The curvature, at a tangent distance of one mile, is eight inches, nearly.

To find curvature:—

To the square of the earth's semi-diameter (3,985 miles) add the square of the given tangent distance. From the square-root of this sum, subtract the earth's semi-diameter; the difference is the true dip.

Or, multiply the square-root of the height of the eye in feet by 1·2247, and the product is the distance in miles.

MECHANICS.

1. Power of Man.

A man's power equal to raise 10 lbs. 10 feet high per second, for 10 hours per day. $10 \times 10 \times 60 =$ 6,000 lbs. per minute, or 5½ men equal to one Horse Power, which, by Boulton and Watt, is at the rate of 32,000 lbs. one foot high per minute.

Bernouilli reckons a man's power equal to raising 20 lbs. through three feet per second for eight hours per day.

2. Power, Men and Horses.

The work done by an animal is greatest when the velocity with which it moves is one-third of the

greatest with which it can move when not impeded; and the force then exerted, four-ninths of the utmost force the animal can exert at a dead pull.

The utmost force of a man at rest is about 70 lbs., and his greatest walking speed about 6 feet per second at a medium; consequently, $\frac{6}{3} = 2$ feet per second, or about $1\frac{1}{3}$ mile per hour, is the velocity at which he should move, and $\frac{4}{9} \times 70 = 31\frac{1}{9}$ lbs. is the force he can exert with the greatest advantage.

The power of a horse is usually reckoned six times that of a man, or about 420 lbs. at a dead pull. His utmost walking velocity is about 9 feet per second. Hence $\frac{9}{3} = 3$ feet per second, or about 2 miles per hour, is the rate at which he should move, and $\frac{4}{9} \times 420 = 186\frac{2}{3}$ lbs. is the force he will exert when walking most effectually.

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3. Horse Power.

Desaguliers and Smeaton reckon	-	1 = 5 men.
French authors	- - - - - -	1 = 7 ditto.
Gregory	- - - - - - - - -	1 = 6 ditto.

And to equal 420 lbs. at a dead pull.

Sauver reckons a horse to draw		189 lbs. at 3 ft. per second.
Smeaton	- - - - -	raise 550 lbs. to 40 ft. per minute.
Gregory	- - - - - - -	70 lbs. at 3 miles per hour, or $4\frac{2}{5}$ feet per second.

N. B. These were stout London cart-horses.

M. Schulze, of Berlin, results of experiments;—Found a man equal to 29 or 30 lbs., with a velocity equal to $2\frac{1}{2}$ feet per second.

A horse equal to 14 men.

Rondelet reckons a man of mean strength equal to carry equal to his own weight, and to draw equal to $1\frac{1}{3}$ times his own weight.

Coulumb found that the best weight for a man to carry up stairs was $173\frac{4}{5}$ lbs. Avoirdupois; the quantity of action, $183\frac{2}{3}$ lbs. Avoirdupois, raised through one kilometer, or 1,094 yards.

A man to walk under	- - - -	$190\frac{1}{2}$ lbs. Avoir.
But best effc[illegible]	- - - - -	165·3 ditto.
A man returning unloaded	- -	200·7 ditto, will carry.

A man walking without a burthen, exerts one-fifth of his power.

A man labouring the ground is equal to raising 328 lbs. 1,094 yards per day.

Under 14° latitude, men can only perform half the work they can do in France.

A man of ordinary strength, turning a roller by hand, can act a whole day against 30 lbs.; for 10 hours, he will raise 30 lbs. $3\frac{1}{2}$ feet per second.

A person may, for a short time, act against 50 lbs. Two men can draw 70 lbs. easier than one can draw 30 lbs. if the handles are at right angles. Porters accustomed to carry heavy burdens will carry 150, or even 200 lbs.

A man can draw 70 or 80 lbs. horizontally.

If the weight of a man be 140 lbs., he can easily push 27 lbs.

A horse moving three miles per hour can exert a force equal to 80 lbs. (Sam[l] Moore, Adelphi.)

A horse reckoned equal to five men, and will carry 240 to 270 lbs.

He can draw 200 lbs. for eight hours in a day, at $2\frac{1}{2}$ miles per hour.

The above is what a horse can draw over a pulley out of a well.

In a cart, a horse will draw more than 2,000 lbs.

A horse will walk in a circle of 18 feet, but it should be 25 to 30 feet diameter.

		lbs.	ft.
Desaguliers allows a horse to raise		27,500,	1 p' min.
Smeaton	- - - - - - - -	22,916	„
Boulton and Watt	- - - -	32,000	„

Power of a man reckoned equal to 30 lbs. moving 3 feet per second, and walking 8 hours per day.

Power of a horse moving $3\frac{1}{2}$ feet per second, and walking 8 hours per day, equal to 200 lbs.; some say, 300 lbs.

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4. Power of Machines.

The power and resistance are in the ratio of the spaces passed through by each in a given time.

In a compound machine, take the product of all

the teeth of all the wheels that act upon or drive others, for a power, and the product of all the teeth in all the wheels moved by them for the weight; or, instead of the teeth, take the respective diameters; or, there are always two wheels, or a wheel and pinion are wheel and barrel upon one axis. Therefore, call that wheel the flyer, leader or runner, which is acted upon, and the other the pursuer, follower or driver.

The product of all the flyers gives the velocity of the power, and the product of all the drivers the velocity of the weight.

Take the product of all the flyers for the weight, and the product of all the drivers for the power.

If the number of teeth in a wheel be 72, and those in a pinion be 8, then the pinion will turn 9 times round for once of the wheel: thus $\frac{72}{8} = 9$.

Wheels and pinions are generally expressed by fractions, the numerator being the *wheel* and the denominator the *pinion*.

The number of turns in a compound machine may therefore be expressed by a fraction, whose numerator is the number of teeth in the first wheel, multiplied by its number of revolutions, and the denominator, the number of teeth in the wheel that is driven.

Thus, a pinion of 6 teeth acting on a wheel of 57, will make it turn twice, while it turns 19 times itself, therefore $\frac{6 \times 19}{57} = 2$; or, a pinion of 9 teeth acting on a wheel of 81, will make it turn 3 times, while it turns 27 times itself, $\frac{9 \times 27}{81} = 3$; or, a pinion of 12 teeth, and a wheel of 96, gives $\frac{12 \times 32}{96} = 4$; or $\frac{15 \times 44}{110} = 6$.

If this machine is wanted to turn a pinion 120 times for one of the first wheel, this may be performed by one wheel and one pinion, or several, provided the number of turns of all bear the same proportions to each other as that one wheel to its pinion.

To make a pinion of 6 teeth revolve 120 times to one turn of a wheel; the wheel must contain 720 teeth, as $\frac{120}{6} = 120$.

But instead of one, it is more convenient to have more wheels and pinions.

Then, if a wheel of 144 teeth act on a pinion of 12 teeth, on whose axle there is a wheel of 60 teeth, acting on a pinion of 6 teeth; the number of turns made by this last pinion while the first wheel turns one round, will be expressed thus:

$$\frac{144}{12} \times \frac{60}{6} = \frac{8640}{72} = 120.$$

Or, a wheel, 180 teeth, acting on a pinion with 15 teeth, or whose axle is a wheel with 70 teeth, to turn a pinion of 7 teeth; then $\frac{180}{15} \times \frac{70}{7} = \frac{12600}{105} = 120$.

Or, say 3 wheels and 3 pinions.

A wheel of 48 teeth, turning a pinion of 9 teeth, on whose axle a wheel of 40 teeth, turning a pinion of 8 teeth; upon whose axle a wheel of 27 teeth turns a pinion of 6 teeth, $\frac{48}{9} \times \frac{40}{8} \times \frac{27}{6} = \frac{51840}{432} = 120$;

Or, having the same ratios,

$\frac{96}{18} \times \frac{80}{16} \times \frac{54}{12} = \frac{414720}{3456} = 120.$

Rules.

1. If the weight be multiplied into the product of the radii of the axes, and that product divided by the product of the radii of the wheels, the power to sustain the weight will be found.

Ex.—Suppose the weight 6,000 lbs., one axis 6 inches, wheel 34; another axis 5 inches, wheel 35; a third axis 4, wheel 27;

Then $6 \times 5 \times 4 = 120$, and $34 \times 35 \times 27 = 32{,}130$, and 6,000 lbs. $\times\ 120 \div 32{,}130 = 22{\cdot}5$ lbs. power required.

2. If the power be multiplied into the product of the radii of the wheels, and the factor divided by the product of the radii of the axis, the weight which power can sustain will be found.

Ex. Thus, if the power be 22·5, the weight will be 6,000.

3. A power and weight being given, to find the number of wheels, and in each wheel the ratio of the axis to that of the wheel, so that the power applied to the periphery of the last wheel may sustain the weight.

Rules.—Divide the weight by the power, resolve the quotient into the factors which produce it, then will the number of factors be the number of wheels, and the radii of the axes will be to the radii of the wheels, as unity to the several wheels.

Ex. A weight 3,000 lbs., power 60; the quotient is 500, which resolves into factors 4,5,5,5; four wheels are therefore to be made, in one of which the radii of the axis is to the radii of the wheel as 1 to 4; in the others, as 1 to 5.

4. If a power move a weight by means of two wheels, the revolutions of the slower wheel are to those of the swifter as the periphery of the wheel which catches in it.

5. The periphery of the axis of the slowest wheel with the periphery of the swiftest wheel being given, as also the ratio of the revolutions of the one to those of the other, to find the space which the power is to pass over, while the weight acquires a given length.

Rule.—Multiply the periphery of the axis of the slowest into the antecedent term of the ratio, and the peripheries of the swiftest into the consequent term; and to these two products, and the given space of the weight, find a fourth proportional: this will be the space of the power.

Ex. The ratio of the revolutions of the slowest wheel to those of the swiftest to be as 2 to 7, and the space of the weight 30 feet; and let the periphery of the axis of the slowest be to that of the swiftest as 3 to 8. The space of the power will be 280, for $2 \times 3 : 7 \times 8 :: 30 : 280$.

6. The ratio of the periphery of the swiftest wheel and of the axis of the slowest, together with the ratio of their revolutions, and the weight being given, to find the power able to sustain it.

Rule.—Multiply both the antecedents and consequents of the given ratios into each other, and to the products of the antecedents, the product of the consequents, and the given weight, find a fourth proportional; that will be the power required.

Ex. The ratios of the periphery 8 : 3; that of the revolutions 7 : 2, and the weight 2,000; the power will be found $214\frac{2}{7}$.

For $7 \times 8 : 2 \times 3 :: 2{,}000 : 214\frac{2}{7}$.

After the same manner the weight may be found, the power and the ratios of the periphery being given.

7. The revolutions the swiftest wheel is to perform while the slowest makes one revolution being given, together with the space the weight is to be raised, and the periphery of the slowest wheel, to find the time that will be spent in raising it.

Rule.—As the periphery of the axis of the slowest wheel is to the given space of the weight, so is the given number of revolutions of the swiftest wheel to a fourth proportional, which will be the number of revolutions performed while the weight reaches the given height; then by experiment determine the number of revolutions the swiftest wheel performs in an hour, and by this divide the fourth proportional found before; the quotient will be the time spent in raising the weight.

5. Friction.

Amouton, Belidor and Bossuet found friction on an horizontal plane, in proportion to its weight, to

be - - - - - - - - - - - - - -	$\frac{1}{3}$
Bullfincher - - - - - - - - - -	$\frac{1}{4}$
Parent and Euler - - - - - - -	as 7 to 20.

6. Ferguson found

Soft wood on soft wood - - - -	$\frac{1}{3}$	of the weight.
Rough ditto - ditto - - - -	$\frac{1}{2}$	„
Soft upon hard wood - - - -	$\frac{1}{2}$	„
Polished steel on polished wood	$\frac{1}{4}$	„
Ditto - - - on copper - - -	$\frac{1}{5}$	„
Ditto - - - on brass - - -	$\frac{1}{6}$	„

7. Coulumb, on a large Scale.

Oak upon oak - - - - - =	$\frac{1}{2.54}$	pressure.
Pine against pine - - - - -	$\frac{1}{1.78}$	„
Oak against pine - - - - -	$\frac{1}{1.5}$	„
Ditto - - - copper - - - - -	$\frac{1}{5.5}$	„

The longer the rubbing substance remained in contact, the friction is increased,

A pulley, with an iron axle, and brass bush friction $\frac{1}{6}$ of pressure. Ditto, when daubed with tallow, $\frac{1}{11}$. Ditto, when daubed with swine's-grease, $\frac{1}{8\cdot5}$. Ditto, with olive oil, $\frac{1}{8}$ $\frac{1}{7\cdot5}$.

Axis of green oak, bush of guaiacum $\frac{1}{26}$ with tallow.
Ditto - - - - ditto, if small - $\frac{1}{17}$ ditto.
Ditto - - - - ditto, elm - - $\frac{1}{33}$ $\frac{1}{20}$
Ditto - - box, guaiacum - - $\frac{1}{23}$ $\frac{1}{14}$
Ditto - - ditto - - - - - - $\frac{1}{29}$ $\frac{1}{20}$

8. Friction of Wood through Water, by Atwood.

Wood planed smooth, 9 lbs. or 258 square feet when moving, 8 feet per second.

9. Expansion, from Young's Natural Philosophy.

Brass, $\frac{1}{100000}$ of its length for each degree of Fahrenheit.

Copper and gold, somewhat less.

Silver - - - - - somewhat more.

Glass and platinum, less than $\frac{1}{2}$ as much.

Iron and steel, about $\frac{2}{3}$ as much.

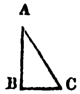
Tin, $\frac{1}{3}$ more.

Lead and Zinc, about $\frac{1}{2}$ as much more.

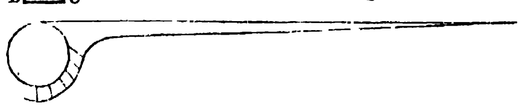
Wood and earth, least expansible of all subjects known.

10. Mills, Under-shot.

The course before reaching the wheel should slope one inch in 200 yards; for the first 48 yards $\frac{1}{2}$ inch. The inclination of fall to be the angle, A B C.



25° 50′ course at top of fall found with a radius of 10$\frac{1}{6}$ inches, the curve at the bottom with a radius of 4 ft. 9$\frac{1}{2}$ in.



Distance of level from bottom curve to the first float-board 2 or 3 feet; from the extremity of the float-board to the bottom of the course should be a space of 3 inches, by a small curved fall concentred with the wheel; the lower part of this should be 9 inches from the extremity of the float-board after the water has passed the wheel; from the curve should be a fall of 8 inches in 16 yards. The tail-water should fall 4 inches in the first 200 yards, 3 inches in the second, &c.

11. To find the Expense of Water.

Measure the depth of the water at A, before it begins to make a curve at the top, also the breadth of the trough at that place. Take the cube of the depth, extract the square root, multiply this by the breadth and also by 488, divide the product by 100, gives the expense in cubic feet in a second.

At E, where the water strikes the float-board, the breadth should be triple the depth, if there is much water, but with a moderate quantity only double; for this divide the square root F E by the quantity of water expended in a second, extract the square root of the quotient, multiply this root by 640, if the breadth is triple, and by 523 if double.

To breadth of course at top, multiply the quantity of water expended per second, by 100 for the first number, take such quantity as you wish for the depth, cube it, and extract the square root, and multiply this by 488 for the second number, divide the first number by the second, and the quotient is the breadth.

N. B.—If the breadth is too much or too little, take half the breadth thus found and add it to the number taken for the depth of water; the sum will be the true depth to renew the operation.

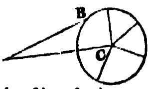
12. Upon an adjusted Course, to find the Quantity of Water expended.

Subtract half the depth of the water at E from E E, multiply the remainder by ·5333.

Extract the square root of the product, multiply this root by the breadth of the course at E; multiply this by the depth of water at this place, the product gives the expense.

13. To find the Velocity.

Multiply the height, viz. F E, less half the depth of the water at E by 64,348; the square root is the product.



The float-board should be $2\frac{1}{2}$ times the depth of the stream at E, and be inclined the value of the angle B A C = 26° 34′.

If the millstone, with its axis and treadle, wei; 1,550 lbs. avoirdupois, take the fall F E more half the natural depth of the water at E, multiply it by the expense of supply in cubic feet; if the product is 30·52 or more, the machine will move without interruption, but not if less.

14. To compute the effective Weight upon an Overshot Mill.

Multiply the constant number 6·12 by half the number of buckets, and this by the number of gallons in each bucket, gives the effective weight, the 3 lower buckets being supposed empty.

This is for a wheel 20 to 30 feet diameter; if under 20 feet, deduct 1 lb. for every foot under 20.

Suppose a wheel 18 feet diameter, 40 buckets, having 2 gallons each.

$6{\cdot}12 \times \frac{40}{2} \times 2 = 244{\cdot}8$, from which deduct 2 lbs., gives 242·8.

Upon an overshot wheel 20 feet diameter, 392 gallons (ale measure) per minute, will grind one boll of corn, Winchester measure, per hour.

That	675 gallons per minute	-	2 bolls.
,,	945	-	3 ,,
,,	1,270	-	4 ,,
,,	1,623	-	5 ,,

Query,—How many bolls by a wheel 25 feet diameter will grind 1,150 gallons per minute?

1st. As 1,270 : 4 : : 1,150 : 3·62 quantity per hour.
2d. As 20 : 3·62 : : 25 : 4·52 bushels.

Query,—To grind $3\frac{1}{2}$ bolls with 2,220 gallons per minute, what diameter the wheel?

1. Find number of gallons a 20 feet wheel requires.

By—as 4 : 1,270 : : 3·5 : : 1,111.

Then—as 1,111 : 20 : : 2,220 : 10 feet.

To find the quantity an undershot wheel will grind with equal water, equal wheel:—

Divide the quantity by an overshot by 2·4, gives the quantity sought.

To know the size of the wheel, to make an undershot equal to an overshot given wheel:—

Multiply the overshot by 2·4, gives the diameter.

The best velocity in practice is when the velocity of the circumference of the wheel moves 3 feet per second; but large wheels may deviate more than small.

Mr. Smeaton had seen a wheel 24 feet diameter move 6 feet, and one 32 feet move 2 feet.

Mr. Smeaton says, when all is well executed, that in an overshot, the work performed will amount to fully $\frac{2}{3}$ of the power expended; viz. 3 cubic feet of water will raise 2 feet to the same height.

The best undershot will, with 3, only raise 1.

Mr. Smeaton says, that $1\frac{1}{2}$ tons of water, falling at the rate of one foot per minute, will grind and dress one bushel of wheat per hour.

This is equal to 9 tons falling 10 feet.

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15. Mr. Fletcher of Chester.

1. To determine the velocity of a wheel, when the radius of the water-wheel 12, the lesser wheel 8, the momentum of the water, and weight or resistance, are given.

Rule.—Multiply the radius of the water-wheel, the momentum of the water, and radius of the small wheel, by the weight or resistance to be overcome; also take their difference.

Then say: As the first product is to the difference, so is the velocity of the water to the velocity of the wheel.

2. For the weight or resistance to be applied to admit that velocity which will produce the greatest effect, the radius of the water-wheel, radius of smaller wheel, and momentum of water, being given.

Rule.—As the diameter of the lesser is to that of the larger wheel, so is the momentum of the water to the resistance required.

3. To determine the lesser or cog-wheel to produce the greatest effect, other things given.

Rule.—As the resistance to be overcome is to the momentum of water, so is the radius of the larger wheel to that of the latter.

4. To find the velocity of the water.

Rule.—Multiply the square root of the height of water in feet above the sluice through which the water issues by 5·4, gives the velocity per second.

5. To find the momentum.

Rule.—Multiply the velocity by the weight of a column of water, whose base is the area of the sluice, and height the depth of it below the surface of the water, gives the momentum.

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16. Example for Momentum.

A stream of water issues through a sluice whose horizontal length is 4 feet, breadth 7 inches, and depth below the surface 10 feet.

Rule.—The square root of the depth 10 is 3·162, which multiplied by 5·4, gives 17·07 the velocity per second.

Again: The area of the sluice is 2·33; this multiplied by the depth 10. and that by 62·5 lbs. (the weight of a cubic foot of water) gives 1546·2; this multiplied by the velocity 17·07 gives 2,485, the momentum.

Example for Proposition 1.

Let the diameter of the water-wheel be 12, the cog-wheel 8, the fall 10, the sluice 4 feet by 7 inches, the resistance of the machinery 18,643: Query, the velocity of water-wheel?

Rule.—The velocity of the water having been determined at 17·07 feet per second, the momentum at 24,857 lbs., then the momentum multiplied by the radius of the wheel (viz. 6) is 149,142, and the resistance multiplied by the radius of the lesser wheel (viz. 4) gives 74,572; the difference of these products is 74,570; therefore, as 149,142 : 74,570 : : the velocity of the water-wheel 8·53 per second.

Example to Proposition 2.

Diameter of water-wheel (viz. 12), cog 8, head and sluice as before; to find the resistance.

Rule.—As the diameter of the cog-wheel 8, is to the radius of the water-wheel 6, so is the momentum of the water 24,857 to 18,643 lbs., the resistance sought.

Example to Proposition 3.

Retaining the numbers as in the preceding Example, we have, as 18,643, the resistance to be overcome, is to 24,857, the momentum of water, so is the radius of the water-wheel (6) to the radius of the cog-wheel (8).

Effects, from Smeaton.

1. Effective head being the same, the effect will be as the quantity of water expended.

2. Expense of water being the same, the effect will be as the effective head.

3. Quantity of water being the same, the effect will be nearly as the square of the velocity.

4. The aperture being the same, the effect will be as the cube of the velocity of the water.

5. The most general proportion between the power and the effect is that of 10 to 3.

Extremes are between 10 to 3·2 and 10 to 2·8. In great works allow 3 to 1.

Effects of overshots nearly double of undershots. Wheel making about 20 turns per minute produces the greatest effect.

Best velocity when circumference of wheel moves about 3 feet per second.

In flat countries, a rule is, to build dams so as not to pen up the water into the wheel of the next mill above, when the water is in its ordinary state; and, further, Mr. Smeaton says, that common mills will bear two feet tail-water, when there is an increase of head; also—

That well-constructed mills will bear 3 or 4, or even 6 feet.

In flat countries, it is usual to lay the wheels from 6 to 12 inches below the water-level of the pond above.

Mr. S. says likewise, that it is the practice of engineers, in levelling, to allow one inch per mile for the least sensible current or drainage.

17. Windmills.

Windmills with four sails, measuring 66 French feet from one extremity to the other, and 6 feet wide, raise 1,000 lbs. 218 feet in 1 minute, and if working on an average 8 hours per day, is equal to 34 men; as it has been estimated that 25 square feet of canvas perform the daily work of a man.

Experiment.—Millers say that a good windmill, that uses from 10 to 11 yards of canvas or sail-cloth, will grind and dress 11 bushels of wheat, will raise 30 millions of lbs. one foot high; therefore 500 bushels would raise 136,636,363 lbs. per week.

AIR.

1. Air

Rushes into a void with a velocity a heavy body would acquire by falling from a homogeneous atmosphere. Air is 840 times lighter than water. The atmosphere supports water at 33 feet; homogeneous atmosphere, therefore, $33 \times 840 = 27,720$ feet.

A heavy body falling one foot, acquires the velocity of eight feet per second.

Velocities are as the square-root of their heights; therefore, to find the velocity corresponding to any given height, expressed in feet per second, multiply the square-root of the height in feet by 8. For air we have $V = \sqrt{2,722} = 8 \times 166,493 = 1,332$ feet per second. This, therefore, is the velocity with which common air would rush into a void.

Or 79,920 feet per minute; some say, 80,880 ditto.

2. Velocity of Wind.

Miles per Hour.	Feet per Second.	Names.	Miles per Hour.	Feet per Second.	Names.
1	1·47	—	30	44·01	Strong gale.
2	2·93	Light airs.	35	51·34	
3	4·40		40	58·68	Hard gale.
4	5·87	Breeze.	45	66·01	
5	7·33		50	73·35	Storm.
10	11·67	Brisk gale.	55	88·02	
15	22·00		80	117·36	Hurricane
20	29·34	Fresh gale.	100	146·70	
25	36·67				

3. Wind's Impulse.

Velocity Feet per Second.	Impulse on a Square Foot, in Pounds.	Velocity Feet per Second.	Impulse on a Square Foot in Pounds.
10	0·229	90	18·526
20	0·915	100	22·872
30	2·059	110	27·675
40	3·660	120	32·926
50	5·718	130	38·654
60	8·234	140	44·830
70	11·207	150	51·462
80	14·638		

Air is 840 times lighter than Water.

N.B.—The resistance of a sphere does not exceed one-fourth of that of its greatest circle.

4. Thermometer.

When first invented, about 200 years ago, air, spirits of wine, and then oil, were made use of; but all these have given way to quicksilver.

Fahrenheit's is used in England, and Reaumur's on the Continent.

The thermometer is on the principle of the expansion and contraction of quicksilver.

Plunge it into boiling water, it stands at 212°, and 32° denotes the freezing-point. Between these, the space is divided into 180.

0 is extreme cold; 32, freezing-point; 55, temperate heat; 76, summer heat; 98, blood heat; 112, fierce heat; 176, spirits boil; 212, water boils.

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5. Experiments in Paris.

$\frac{1}{70}$ of an inch in a yard is $\frac{1}{2520}$ for 90° Fahrenheit.

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6. Barometer.

Mercury is 14 times heavier than water; therefore if the pressure of the atmosphere will balance 34 feet of water, it will only balance $\frac{1}{14}$ part of that height of mercury, viz. a little more than 29 inches.

If the air is dense, the mercury rises in the tubes and indicates fine weather; if the air becomes lighter, the mercury falls and indicates rain. Standard altitude in England varies between 28 and 31 inches; the difference is called the state of variation.

Near the tropics there is little or no variation. In Russia (Petersburg) about 3½ inches; when the barometer stands at 1·30 inches, the specific gravity of the atmosphere is 800 times lighter than that of water, but mercury is 14 times heavier than water, consequently the specific gravity is to that of air as 800 multiplied by 14 is to 1, or mercury is 11,200 times heavier than air, or $11,200 \times 30 = 336,000$ inches, or 5½ miles nearly.

But air, by its elastic quality, at 3½ miles above the surface of the earth, is twice as rare as if at the surface; at 7 miles, 4 times; at 10½ miles, 8 times; at 14 miles, 16 times.

From experiments and calculations it is admitted, that the atmosphere reaches 45 or 50 miles above the earth's surface.

In ascending the Puy de Dome, a mountain in France, the quicksilver fell 3$\frac{1}{?}$ inches; the mountain measured 8,204 feet in height. In ascending Snowdon in North Wales, the quicksilver fell 3$\frac{8}{10}$ inches, at the height of 3,720 feet above the sea.

Therefore it is inferred, that in ascending, the mercury will fall $\frac{1}{10}$ of an inch for every 100 feet perpendicular.

When the barometer stands at 29·5, the pressure of the air upon every square inch is more than equal to 14 pounds.

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7. Gas.

At Edinburgh, coal-gas is manufactured at the rate of 8*s.* per 1,000 cubic feet, and sold for 12*s.*

Oil-gas costs 26*s.* per 1,000 cubic feet; the oil at 2*s.* per gallon.

In 1824, the extent of gas-pipe about London exceeded 900 miles.

WATER.

1. Water.

To find the pressure of a column of water in lbs. Avoirdupois.

If the base is circular,—Take the diameter in inches, and the height in feet: square the diameter in inches, and multiplying by the decimal ·341, or by ·34, this gives the weight of 1 foot in height; therefore, multiplying by the number of feet in height, gives lbs. Avoirdupois.

If the base is square, multiply by the decimal ·434.

In great works, take the area of the base in feet, multiply by 62·5, if square, and if circular, 49·0875, and that by the height in feet.

To find the pressure against the whole side or bank of a reservoir or tank.

Say 18 feet long and 6 feet deep.

Then $\frac{2}{3}$ of 6 (being the centre of pressure) is 4. Then $4 \times 62{\cdot}5 = 250$ lbs., being the mean pressure

upon each square foot of the plane, and the length $18 \times 6 = 108$ square feet $\times 250 = 27,000$ lbs., the pressure against the whole area.

Mr. Watt observed that in a canal 18 feet wide at top, 7 at bottom, and 4 feet deep, having a fall of 4 inches in a mile, the velocity was 17 inches per second at top, 14 middle, and 10 at bottom; the mean velocity may be called $13\frac{3}{4}$ per second.

To find the hydraulic mean depth, divide the area of the section $\left(\frac{18 \times 7}{2}\right) \times 4 = 50$ square feet, by the breadth of the bottom, and length of the sloping sides added together; whence $\frac{50}{20\,6}$ or 29·13 inches; and the fall in 2 miles being 8 inches, we have $\sqrt{(8 \times 29{\cdot}13)} = 15{\cdot}26$ for the mean proportional, $\frac{10}{11}$ of which is 13·9, agreeing with Mr. Watt's observation.

Therefore, note that the velocity in inches per second is $\frac{10}{11}$ of a mean proportional between the hydraulic mean depth and the fall in two English miles in inches. *N.B.* This supposes a strait equable channel.

Extract the square root of the depth in inches, and multiply it by 138·88; the product is the velocity in feet per minute. This is without reference to friction.

Therefore, multiply the velocity obtained by 618, or measure the depth of the centre of the orifice beneath the surface of the reservoir in inches, extract the square root, and multiply by the constant number 85·87; the product is the velocity in feet per minute.

2. Pressure of Water and Velocity.

Pressure is as the square of the depth.

Discharge as the square root of the depth.

To find the pressure against a bank or sluice, multiply the area by $\frac{1}{2}$ the depth, and that by $62\frac{1}{2}$ for river, and 64·4 for sea-water, gives the pressure in lbs. Avoirdupois.

To ascertain the discharge over a Weir:—

A head of 16 feet gives a velocity of 32; and the ratio of velocity is as the square root of the depth:

Therefore, as the $\sqrt{16}$, that is 4 : is to 2, the $\sqrt{4}$: so is 32, the velocity of 16; to 16, the velocity of 4:

Or, if the square root of the depth in feet be multiplied by 8, gives the velocity in feet per second.

3. Over a Waste Board

Depth, inches.	Cubic feet per minute over every inch.		Depth, inches.	Cubic feet per minute over every inch.	
1	0·403	0·428	10	12·748	13·355
2	1·140	1·211	11	14·707	15·632
3	2·095	2·236	12	16·758	17·805
4	3·225	3·427	13	18·895	20·076
5	4·517	4·789	14	21·117	22·437
6	5·925	6·295	15	23·419	24·883
7	7·466	7·938	16	25·806	27·413
8	9·122	9·692	17	28·250	38·024
9	10·884	11·562	18	30·706	32·716

The third experiment made in Scotland.

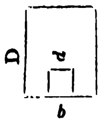
Discharge of pipes, is as the square of the diameter of the pipe, and the square root of the depth.

Square the diameter of a pipe in inches, gives the lbs. Avoirdupois in a yard in height of water; divide by 10, gives the ale gallons.

Ale gallon contains -	282 cubic inches.	
Wine gallon - - -	231 ditto.	
63 gallons - - - -	one hogshead wine.	
64 „ - - - - - - -	„ -	ale.
72 „ - - - - - - -	„ -	beer.

In London, ale barrel contains -	32 gallons.
„ beer ditto - - - -	36 „

Water out of a Vessel.



D, the depth of the bottom of an aperture below the surface of the water.
d, ditto to the top of aperture.
b, breadth of aperture.

Then $\frac{\sqrt{D^3}-\sqrt{d^3}}{D-d} \times 5{\cdot}34 =$ mean velocity.

$\sqrt{D^3}-\sqrt{d^3} \times 5{\cdot}346 =$ quantity discharged.

If the aperture is in the bottom of the vessel, then $8 \times \sqrt{D} =$ velocity; and this multiplied by the area of the aperture, gives the quantity.

---

4. Water over a Wier or open Notch.

Dr. Robison found the depth of water in the aperture about ·715 of the whole depth from the bottom of aperture to the surface of the water in the reservoir.

Note that 11·4491 cubic inches, or 11·5, will be discharged in a second through every inch in width of the aperture, when the bottom is exactly one inch below the level of the surface of water in the reservoir. Therefore, for any other depth, this number might be multiplied by the square root of the cube of the depth in inches, and it will give the cubic inches discharged per second through every inch in width of aperture.

Thus, when the bottom of an aperture is 4 inches below the surface of water in a reservoir, then the cube is 64, the square root is 8; therefore, at this depth each inch in width will discharge $8 \times 11{\cdot}5 =$ 92 cubic inches per second. If the width is 3 feet, then $92 \times 36 = 3{,}312$ cubic inches per second.

Note.—If the aperture is not in the side of a large reservoir, but in a running stream, we must augment the discharge by multiplying the section by the velocity of the stream.

Friction to be allowed according to the kind of board over which the water flows, nearly the same as in orifices.

Table by Dr. *Robison.*

Depth from bottom of Aperture to level surface of Water, in Inches.	Cubic feet discharged per minute, through each inch of width of Aperture. In Apertures less than 18 inches wide.	In Apertures more than 18 inches wide.
1	0·403124	0·428
2	1·140	1·211
3	2·095	2·226
4	3·225	3·427
5	4·507	4·789
6	5·925	6·295
7	7·466	7·933
8	9·122	9·692
9	10·884	11·564
10	12·748	13·535
11	14·707	15·632
12	16 758	17·805
13	18·895	20·096
14	21·117	22·437
15	23·419	24·883
16	25·800	27·413
17	28·258	30·024
18	30·786	32·710

Table by Dr. *Robison—continued.*

Description of Aperture.	Mean Velocity in feet per minute. *Rule:*-Multiply the square root of the depth in inches by some one of the following numbers, according to circumstances.	Number of cubic feet per minute through each inch, in width of Aperture. *Rule:*-Multiply the square root of the cube of the depth in inches by some of the following numbers.
Small aperture:—their edges apart not to exceed 18 inches long by 1 deep - -	57·246	·39754
Edges ½ to an inch	58·0493	·40312
If more than 9 inches deep and edges 2 inches -	58·88	·40886
If kept level with bottom of Weir, of broad stone walls - -	88·92	·6174
Full discharge, by having no (side) friction - -	92·592	·6430

5. Quantity of Water flowing in 24 hours, from a Basin or Reservoir of still water, over a Horizontal Notch or Aperture, one foot in breadth, cut in a Plank: [apparently calculated from Dr. Robison's preceding Formula, *J. R.*]

Depth.	Quantity.	Depth.	Quantity.
Inches.	Cubic feet.	Inches.	Cubic feet.
·25	1,000	11·0	260,000
·43	2,000	11·5	278,000
·55	3,000	12·0	296,000
·66	4,000	12·5	314,000
·78	5,000	13·0	333,000
·87	6,000	13·5	352,000
·97	7,000	14·0	371,500
1·0	7,400	14·5	392,000
1·5	13,000	15·0	413,000
2·0	20,000	15·5	434,000
2·5	28,000	16·0	455,000
3·0	37,000	16·5	476,000
3·5	47,000	17·0	498,000
4·0	57,000	17·5	521,000
4·5	68,000	18·0	544,000
5·0	79,000	18·5	567,000
5·5	91,000	19·0	590,000
6·0	104,000	19·5	613,000
6·5	117,000	20·0	637,000
7·0	131,500	20·5	661,000
7·5	145,500	21·0	685,000
8·0	160,000	21·5	709,000
8·5	175,000	22·0	733,000
9·0	191,000	22·5	758,000
9·5	208,000	23·0	783,000
10·0	225,000	23·5	808,000
10·5	242,000	24·0	833,000

The quantity, at 24 inches deep, is about 833,000 cubic feet, say 833 thousand.

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6. River Jetties.

In the new channel of the river Dee, below Chester, Mr. Wedge finds that the jetties for regulating the channel produce the best effect when placed from 160 to 200 yards apart.

Each jetty contains about 500 tons of stones.

7. Rivers, taken in Inches per Second.

$\overline{\sqrt{\text{of superior velocity}}-1}\,\rceil^{2}$ = bottom velocity.

$\dfrac{\text{Bottom veloc.} + \text{top veloc.}}{2}$ = mean velocity.

or, top veloc. — $\sqrt{}$ of top veloc. = mean velocity.

or, top veloc. + 1—2 $\sqrt{}$ top veloc. = both velocities.

Pressure of water against one side of a cubical vessel, filled with a fluid, is equal to half the pressure against the bottom; and the whole pressure against the sides and bottom is equal to three times the weight of the fluid in the vessel.

Effect of water on a foot square of surface, with a velocity of one foot per second, is 1 lb. 7 oz. (Bouger.)

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8. Running Water.

6 inches per second will lift fine sand.
8 - - - - - - - - - - sand as large as flint-sand.
12 - - - - - - - - - fine gravel.
24 - - - - - - will roll along pebbles one inch diameter.
36 - - - - - - will sweep angular stones as large as a hen's egg.

Co-efficients for Orifices of different kinds.	Rates between the theoretical and real Discharge.	Co-efficient for the Velocities, in English Feet.
For the whole velocity due to the height - - -	1 to 1·00	8·04
For a wide opening whose bottom is on a level with that of the Reservoir - -	1 to 0·961	7·7
For streams with walls in a line with the orifice - -	1 to 0·961	7·7
For Bridges with pointed Piers	1 to 0·961	7·7
For narrow openings whose bottom is on a level with that of the Reservoir - -	1 to 0·861	6·9
For smaller openings in a Sluice with side-walls - - -	1 to 0·861	6·9
For abrupt Projections and Square Piers of Bridges -	1 to 0·861	6·9
For openings of Sluices without side-walls - - -	1 to 0·635	5·1

9. Water Pipes.

Water presses towards an orifice in all directions, and diminishes the velocity in the proportion of 63 to 100, nearly; or, the quantity delivered through an orifice will be less in this proportion than by calculation by the laws of falling bodies.

If there is a widening in a pipe, which is otherwise uniform, to make the delivery the same as if there had been no enlargement, requires an additional force equal to the weight of a column of water of the height necessary for communicating a velocity, the square of which is equal to the difference of the squares of velocity of the water in the wide and narrow part of the conduit.

The same as to air.

10. Jet of Water.

La Meule, in Languedoc; produce of water from a hole 8 inches in breadth and 6 inches high, with a head of 8 or 9 feet, producing 85 cubic toises per hour.

Le Pouce; produce per minute from a hole one inch in diameter, with the water one line above its upper surface. This requires the surface of the water in the reservoir to be two lines, producing, in 24 hours, 576 cubic feet, or 40,320 lbs.

11. Ratios between Real and Theoretical Velocity. Depth taken from top surface, through the centre of Orifice.

For orifices in a thin plate - - -	·618
Opening in sluices without side-walls -	·636
Where there is a short cylindrical pipe projecting inside vessel, length two to four times bore, and rims like contracted veins; not full - - -	·5137
Ditto, when it runs full bore of water -	·681
Ditto, when it does not project within vessel - - - - - -	·8125
Narrow openings, bottom on a level with that of reservoir, also sluices with side-walls, and piers of bridges with square ends - - - -	·860
Wide opening, bottom on a level with that of reservoir, with conducting walls, and waterway through piers of bridges with conducting points -	·960
A circular tube, fitted to contracted vein or stream - - - -	·983
The whole velocity, according to theory of falling bodies - - - -	1·000

12. Water Gauge.

1. By a screw or spiral machine, with its end to the reservoir or supply, having also an index. The water passing during one revolution being ascertained, the number of revolutions gives the quantity in a given time.
2. By a sluice moveable by floats upon the top of the reservoir or supply, and the water supplied passing over the top of the sluice.
3. By a pipe with a moveable joint being fixed at the end of the main pipe, the moveable pipe being regulated by float-boards on the top of the reservoir or supply.

13. Pump.

Piston must be within 30 or 32 feet of the surface of the water in the wells; but as to the valve it is of no consequence at what part of this distance it is placed, as the pressure of the atmosphere will raise the water. The weight of water at each stroke is that of a column, whose height is from the surface of the water in the well to the spout or discharge, and its diameter the bore where the bracket works; therefore, as the length of the longer arm of the lever is to the shorter, so is the power to the weight.

Ferguson says, that the force required is as the height to which the water is raised, and the square of the diameter of the bore where the piston works.

The longer generally exceeds the shorter arm five or six times.

If the handle be a lever, increasing the power five times, an ordinary man will work a pump four inches bore where the piston works, and raise 27 ½ gallons 30 feet high in a minute. Square the diameter in inches, gives the weight in pounds avoirdupois; divide the product by 10, gives the number of gallons per yard.

If any force be applied to a lever, its effect is as the force multiplied by its distance from the centre of motion, and by the size of the angle of the direction of that force.

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14. London Supply.

Mr. *Hume*'s Speech, 14 June 1820.

In 1809. Supply 118,469,175 hogsheads to 91,841 buildings, £.121,528 rent.

In 1820. Supply, 155,381,038 hogsheads to 120,732 buildings, £.163,000 rent.

East London Waterworks charge 22*s.* per annum for daily supply, 135 gallons.

West Middlesex - ditto - charge 50*s.* per annum for daily supply, 174 gallons.

Grand Junction - ditto - charge 57*s.* per annum for daily supply, 278 gallons.

15. Dalton on Evaporation.

		Inches.
Mean rain in 1796–97–98; in a year	=	33·55
Ditto, of water passed through pipes in ground	=	8·11
Evaporated		25·14

Evaporated from surface of water - - - 44·43

In 1793, Mr. Dalton published a volume of Meteorological Essays.

In 1802, ditto, in 5 vols. Manchester Transactions; a series of Essays.

16. Rain falls.

Mr. Dalton reckons, that on the average, in England, Rain fa - - - - 31, Dew - - - - - 5 } 36 inches.

Of this, Evaporation 23, Rivers - - 13 } 36

Thames said to carry annually to the sea 166,624,128,000 cubic feet.

Severn and Humber, each as much.

M. J. Sganzin, Prof. Ecole Polytechnique, says, evaporation from a water-surface is found, by experiment, to be 0·865 metre per annum, being about 30 French inches.

STEAM ENGINES.

1. Steam Engine.

Calculation for Cylinder and Pump.

1. To find the number of gallons to be drawn at one stroke; divide the number to be drawn in one hour per day by the number of strokes.

2. Multiply the number of ale gallons to be drawn at one stroke by the constant number 5, and from that product extract the square root; this will be the diameter.

3. Multiply the depth or fathoms by the constant number 2·604, and divide the product by the number of pounds upon every inch of the piston's surface; extract the square root of the quotient, and multiply the root by the surface diameter, gives the diameter of the cylinder.

N. B.—The above is for a six-feet stroke.

But if for a Nine-Feet Stroke.

1. Divide 6 by the length of the proposed stroke, and multiply the quotient by five times the number of gallons to be lifted at a stroke; from this product extract the square root, gives the pump's diameter.

2. Multiply the depth in fathoms by the number of gallons to be raised at a stroke, and multiply

that product by the constant number 13·07; divide the last product by the pressure in lbs. upon one inch; extract the square root, gives the diameter of the cylinder.

It is found by experience, that a cylinder 40 inches diameter, will work a pump 10 inches diameter, 100 yards long. From this find others.

Dr. Young says, a steam engine in London, with a 24-inch cylinder, does the work of 72 horses, and consumes a chaldron of coals each day, each bushel being equivalent to two horses, and each square inch of the cylinder performing nearly the work of a man.

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2. Messrs. *Boulton* and *Watt* state—

112 lbs. of coals will raise 20,000 cubic feet of water 24 feet high.

84 lbs. of coals will raise 30 millions of lbs. one foot high. (*See* Cornish Engines.)

Reckon one-horse power equal to raising 3,300 lbs. 10 feet high per minute.

84 lbs. Newcastle coals, 112 lbs. Staffordshire, 120 lbs. Shropshire, all equal in power for producing steam.

PRICES—*Boulton* and *Watt*.

		Ft. stroke.		£. cost.
36 horse power,	48 cylinder	8	40	2,441
20 - ditto	36 - ditto	8	30	1,609
12 - ditto	24 - ditto	5	21	851

Delivered at manufactory.

By the Register in Cornwall.

An average of the engines, raised only 13,500,000 lbs. one foot high, by one bushel of coals of from 84 to 88 lbs.

In 1815, they raised 21,500,000 by an average of 33 engines.

In 1816, the three best engines raised 31¼, 31, 29, 28½, 26½, 22½ millions of lbs. one foot high, by a bushel of coals.

Newcomen's engine, at Long Benton colliery, with one bushel of coals, raised 504,415,814 lbs. one foot high. By Mr. Smeaton, in 1772.

Pumping Engine at Fort Augustus—*Boulton* and *Watt.*

36 horse power consumed 4½ tons of coals in 24 hours.

Ditto at Corpach, 20 horse power, 1½ tons of coals in 24 hours.

Every horse power to raise 3,300 lbs., or 53·2 cubic feet of water 10 feet in a minute.

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3. STEAM ENGINE,—*Banks.*

Put $d=$ diameter steam cylinder in feet.

$q=·7854$.

$l=$ length of stroke in feet.

$p=$ pressure per foot in lbs.

$w=62·5$ weight of water.

$h=$ number of feet to be raised.

$c=$ diameter of pump in feet.

$g=6·1276$ ale gallons per foot cube.

$h=10·28$ cubic feet in a hogshead.

Then will

$q\,d^2=$ area of the piston in feet.

$p\,q\,d^2=$ weight of water to be lifted in lbs.

$\frac{p\,q\,d^2}{w}=$ cubic feet of water in pump, which divided by h gives

$\frac{p\,q\,d^2}{h\,w}=$ area of the pump's piston in feet, which multiplied by l gives

$\frac{l\,p\,q\,d^2}{h\,w}=$ cubic feet water raised per stroke.

From which equation we have the following theorems:—

Theo. 1. $d=\sqrt{\frac{w\,h\,c^2}{p}}$.

Theo. 2. $c=\sqrt{\frac{p\,d^2}{h\,w}}$.

Theo. 3. $h=\frac{p\,d^2}{w\,c}$.

Theo. 4. $l\,q\,c^2=$ cubic feet per stroke.

Theo. 5. $g\,l\,q\,c^2=$ gallons per stroke.

Ex.—Given diameter steam cylinder 3 feet, length of stroke 6 feet, depth well 50 feet; required diameter of pump, and quantity of water raised per stroke?

Here we have given diameter of steam cylinder $3 = d$; length of stroke, $6 = l$; depth, $50 = h$, to find c.

Which by Theo. 2. $= \sqrt{\frac{p d^2}{h w}} = \sqrt{\frac{7515}{3125}} = 1{\cdot}55$ feet, and the quantity per stroke is by Theo. 4. $= l q c^2 = 6 \times 7{,}854 \times 2{,}404 = 11{,}328$ cubic feet.

In the above p is taken at 835 lbs. instead of 1,245, which it ought, if free from friction, &c.

Ex. 2.—Given diameter of pump one foot, height 240 feet, to find diameter of steam cylinder.

Here we have $w = 62{\cdot}5$ lbs. : $h = 240$; $c = 1$; and $w h q c^2 = p d c^2 =$ the whole weight of the cylinder of water to be lifted. From which we find, Theo. 1. $d = \sqrt{\frac{w h c^2}{p}} = \frac{15000}{835} = \sqrt{17{\cdot}96} = 4{\cdot}23$ feet diameter required.

Ex. 3.—Given quantity of water to be raised in one hour 200 hogsheads, depth 100 yards, length of stroke 6 feet, number of strokes per minute 10; required diameter of cylinder and pump.

200 hogsheads $= 12{,}600$ gallons, which, divided by 600, the number of strokes, gives 21 gallons per stroke; therefore, Theo. 5. $21 = g l q c^2 =$ and $c = \sqrt{\frac{21}{g l q}} = 852$ feet, or $10{\cdot}22$ inches, the diameter of the pump, and per Theorem 1. $d = \sqrt{\frac{w h c^2}{p}} = 4{\cdot}04$ feet, the diameter of cylinder.

N.B.—If the weight of the pump rods and plug frame be taken into the computation, let their weight, when the weight of the steam piston is taken from them, be put $= h$ pounds. Then $d = \sqrt{\frac{w h c^2}{p} + \frac{n}{q p}}$, and $c = \sqrt{\frac{p d^2}{h w} - \frac{h}{q h w}}$.

Ex. 4.—Required the dimensions of an engine to raise 250 hogsheads per horse to the height of 55 yards, the weight of the rods being 2,000 lbs.

$250 \times 63 = 15{,}750$ gallons per horse, which, at 12 strokes per minute, is 22 gallons per stroke, $= 3{\cdot}59$ cubic feet $= q l c^2$, and $c^2 = \frac{359}{q}$, $=$ the square root of which is $\cdot 87$ feet, or $10{\cdot}4$ inches, the diameter of the pump, and $d = \sqrt{\frac{w h c^2}{p} + \frac{h}{p q}} = 3{\cdot}53$ feet, the diameter of the cylinder.

Messrs. Boulton and Watt suppose a horse capable of raising 33,000 lbs. Avoirdupois one foot high per minute.

Smeaton - - - - - - -	22,916 lbs.
Desaguliers - - - - -	27,500 lbs.

Therefore divide the number of pounds raised by a steam-engine by any of those numbers, gives the number of horses each of those persons reckon upon. But as this power works 24 hours, it is equal to three times the number of horses.

An engine with a cylinder 31 inches, making 17 double strokes per minute, equals 40 horses working day and night, and burns 11,000 pounds weight of Staffordshire coal per day of 24 hours.

A cylinder 19 inches diameter, 25 strokes of 4 feet each per minute, is equal to 12 horses working day and night, and burns 3,700 lbs. of coal per day.

A cylinder 24 inches, 22 strokes 5 feet per minute, is equal to 20 horses working night and day, and burns 5,500 lbs. of coal.

Boulton and Watt estimate, that one bushel of Newcastle coals, containing 84 lbs. (London bushel = 88 lbs.) will raise 30 millions of pounds one foot high.

Ditto - will grind and dress 11 bushels of wheat.

Ditto - will slit and draw into nails 5 cwt. of iron.

Ditto - will drive 1,000 cotton-spindles, with all their machinery.

These are equal to 10 horses.

4. Fly-wheels.

A force equal to 20 lbs. applied 37 seconds to the circumference of a cylinder, 20 feet diameter, which weighs 4,713 lbs., would, at the distance of one foot from the centre, give an impulse to a musket-ball equal to that it receives from a full charge of gunpowder.

In the space of 6 min. 10 sec. the same effect would be produced, if the cylinder was worked by a man who constantly exerted a force of 20 lbs. at a winch one foot long.

Woolf's Table.

	lbs. per sq. inch.		Degree of Heat.			
	5		227 ½		5	
Steam of	6		230 ¼		6	times its
even elastic	7	requires	232 ¾		7	volume,
force predo-	8	to be	235 ¼	and at these	8	and con-
minating	9	maintain-	237 ½	respective	9	tinues
over the	10	ed by a	239 ½	degrees	10	equal in
pressure of	15	tempe-	250 ½	of heat,	15	elasticity
the at-	20	rature	259 ½	steam can	20	to the
mosphere	25	equal to	267	expand it-	25	pressure
upon a safety	30	about	273	self to about	30	of the at-
valve.	35		278		35	mosphere.
	40		282		40	

5. Steam-boat,

Fourteen-horse power, allowed 160 lbs. of Newcastle coals per hour. On the Clyde, thirty-three-horse power consumes 3 tons 12 cwt. in going and coming between Glasgow and Greenock; that is, one journey of $29 \times 2 = 54$ miles.

From Mr. Palmer. Horses generally employed in navigations exert 125 lbs. at $2\frac{1}{2}$ miles per hour.

Average strength of horses reckoned 150 lbs. at same rate. Steam-engine calculated at this:—one bushel of coals per horse for each horse power.

6. Steam-Boat.

Dividing $186\frac{2}{3}$ by $3\frac{2}{3}$ = sq. velo. per sec. in feet =21, nearly, for the pressure at one foot per second; and valuing that at ½ lb. per square foot, 42 square feet seems the proper area for a boat tracked by one horse in still water.

Twenty-four feet of steam per min. = one horse power.

One foot of gas, yielding 24 feet vacuum, equal to one horse.

A pneumatic engine of one horse power should consume 60 cubic feet per horse, or 1,500 per day, or at Edinburgh, $\frac{1}{6}$; and the cumbersome steam-engine would be got rid of.

[*Much of this article has become inapplicable, from recent improvements.*]

7. Coals.

Lightest weight, 74 lbs. per cubic foot.
Heaviest „ 79 lbs. ditto.

Ton of coals, as sent from the mine, is equal to 50 cubic feet in water.

When interstices filled with slack, 45 will weigh a ton.

A solid coal, of one cubic yard, equal to 5 bolls, broken to pieces of considerable size, will measure 7 ½ bolls; if broken very small, 9 bolls.

TIMBER.

1. Timber.

Oak: For strength and durability, choose that which is slowest of growth; of two pieces equally dry, choose the heaviest, and that which will be least changed by being soaked in water.

In similar soils, trees growing next the outside of the forest are more durable than those nearer the middle; and in the same tree, the side next the north is stronger than that to the south.

Trees should be cut during winter, when free from sap.

In trees cut before they have passed their prime, the outward rings or coats begin first to decay, when exposed to damp situations; but in old trees, the decay begins at the central parts. In bad soils there is least sap.

In Ash there is little difference of quality through the whole thickness; the outside is rather the toughest; it ever rots when exposed to the weather; lasts long when protected.

2. A Square Inch will suspend:

By *Muschenbroek.*

	lbs.		lbs.
Locust-tree - -	20,100	Elder - - -	10,000
Beech and Oak -	18,500	Fir - - - -	8,330
Alder - - - - -	15,500	Pitch Pine - -	7,650
Elm - - - - -	13,200	Poplar - - -	5,500
Willow - - - -	12,500	Cedar - - -	4,880
Ash - - - - -	12,000		

Muschenbroek made his experiments on pieces one-fifth of an inch square.

A rod of fir, 2 inches diameter, will bear 7 tons, and no more.

3. Buffon's Experiments upon Timber.

Col. 1. Length, in feet, between the props.
" 2. Weight of piece, second day after felled, in lbs.
" 3. Number of lbs. necessary to break it in a few minutes.
" 4. Inches bent in time of breaking.
" 5. Time in which it broke.

1.	2	3.	4.	5.
7	60	5,350	3·5	29
	56	5,275	4·5	22
8	68	4,600	3·75	15
	63	4,500	4·7	13
9	77	4,100	4·85	14
	71	3,950	5·5	12
10	84	3,625	5·83	15
	82	3,600	6·5	15
12	100	3,050	7·	–
	98	2,925	8·	–

Muschenbroek says, that a piece of sound oak, $\frac{27}{100}$ of an inch square, is torn asunder by 1,150 lbs.; and that an oak plank, 12 inches broad and one inch thick, will suspend 189,163 lbs.; gives = 15·755 per square inch.

Bouger gives 16,000 lbs. per square inch.

N.B. One third part only of the weights should be reckoned on in practice.

4. Beams of various Dimensions.

Length in feet.	4 inches square.	5 inches square.	6 inches square.	7 inches square.	8 inches square.	A.
7	5,312	11,525	18,950	32.200	47,649	11,525
8	4,550	9,787	15,525	26,050	39,750	10,085
9	4,025	8,308	13,150	22,350	32,800	8,964
10	3,012	7,125	11,250	19,475	27,750	8,068
12	2,987	6,075	9,100	16,178	23,450	6,723
14	- -	5,300	7,475	13,225	19,775	5,763
16	- -	4,350	6,362	11,000	16,375	5,042
18	- -	3,700	5,562	9,245	13,200	4,482
20	- -	3,225	4,950	8,375	11,375	4,034
22	- -	2,975	- -	- -	- -	3,667
24	- -	2,162	- -	- -	- -	3,362
28	- -	1,775	- -	- -	- -	2,881

The column A. exhibits the strength which each of the 5-inch beams ought to have by the theory.

As particles vary at the time of practice, say as thrice the length is to the depth, so is the absolute cohesion to the relative strength. Also the relative strength is proportional to the breadth and square of the depth directly, and to the length inversely, for p is the measure of the force, and $p = \frac{f\,b\,d}{l}\,\frac{d}{3} = \frac{f\,b\,d^2}{3\,l}$.

But from impressibility, say six times the length is to the depth as the absolute cohesion is to the relative strength.

Force exerted in breaking two cylinders are as the squares of the diameters.

The strength is increased by fastening the ends of beams, as 2 to 3; by theory, as 2 to 4.

Since the strength of timber beams is as the breadth, the square of the depth, and inversely as the length:—

Measure the breadth and depth in inches, and the length in feet.

A beam 4 inches square, and 7 feet between the props, is broken by 5,312 lbs.; a batten, one inch square, by 584: therefore, any other oak beam will just break when it is loaded with $584\,\frac{b\,d^2}{l}$.

For a radical number add to 5,312 the number 640, gives 5,952; the 64th of this is 93, which corresponds to a bar one inch square, and 7 feet long; therefore 93×7 will be reciprocal, corresponding to a bar of one foot; this is 651; from this take $\frac{640}{64}$, or 10, leaves 641 for the strength.

Rule: $p = 651 \times \frac{b\,d^2}{l} - 10\,b\,d^2$.

Example.—Beam 8 inches square, 20 feet long between props, $p = 651 \times \frac{8 \times 8^2}{20} - 10 \times 8 \times 8^2 = 11515$.

Simple Rule.

Multiply breadth in inches by the square of the depth, and call this product f. Multiply f by 651, and divide by the length in feet. From the quotient

take 10 times f, leaves the number of lbs. which will break the beam.

N. B. The above breaks the beam in a few minutes; $\frac{2}{3}$ impaired its strength, and frequently broke it in two or three months;

$\frac{1}{2}$ bent it, but after a few minutes it did not go further;

$\frac{1}{3}$ had no effect, therefore use this.

Buffon makes fir - - - - -	$\frac{6}{10}$ of oak.
Parent - - - - - - - - - -	$\frac{12}{10}$ „
Emerson - - - - - - - - -	$\frac{2}{3}$ „

5. Canadian Bridge.

Mr. Porter made a wooden trussed bridge of 750 feet over the Terrebon, a branch of the St. Lawrence, carried away by a flood, soon after erected. A model was deposited in the Tower by Major By, of the Royal Engineers.

Prefers Wiebeking's scheme.

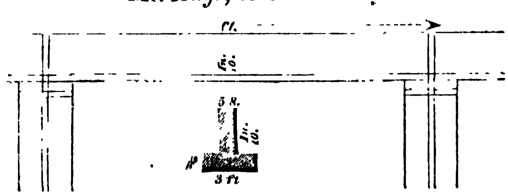
IRON.

1. Experiments at *Wakefield*, with a bar one inch square, weighing 9 lbs. per yard, with props 3 feet apart.

1st broke with 963 lbs. }
2d „ 958 „ } These all bent one inch before they broke.
3d „ 994 „ }
4th broke with 864 lbs. from cupola irons.
5th, weight 6 lbs. 3 oz., 874 lbs. end of the parabolic.

Mr. Banks concludes that the cast-iron is from $3\frac{1}{2}$ to $4\frac{1}{2}$ times stronger than oak, and from 5 to $6\frac{1}{2}$ times stronger than deal of equal dimensions.

Mr. *Bage*, of Shrewsbury.



This best iron bar, 9 feet long, and of the dimensions shown by the elevation and section, required fourteen tons laid upon the middle of its length to break it, and 26 distributed over the whole of its length.

The bar weighed 2 cwt. 3 qrs.

2. Experiments at *Colebrook Dale*, April 1795.

Rib, 29 feet 6 inches span; 11 inches high in centre; bore 99 cwt. 1 qr. 14 lbs.; it sunk $3\frac{7}{8}$, and rose again $\frac{3}{4}$, when weight was removed.

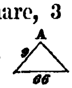
Same rib, without abutments, broke with 53 cwt. 0 qr. 14 lbs.

Another rib, 29 feet 3 inches span, segment of a circle, 3 feet high in centre, bore 100 cwt. 1 qr. 14 lbs., and sunk $1\frac{3}{16}$ in the middle.

The same rib, without abutments, broke with 64 cwts. 1 qr. 14 lbs.

3. Experiments at *Ketley*, in March 1795.

Bars all cast at once from the same air furnace; the iron very soft.

2 bars one inch square, 3 feet long, placed on a horizontal bar, thus  to meet in a cap at A, at an angle of 45° from the cap: 7 tons remained suspended 16 hours, after which the bars were only bent a little.

Two more bars of same dimensions were placed, making an angle of $22\frac{1}{2}$ degrees with the horizon; they bore 4 tons.

Another bar laid upon props 3 feet distant bore $6\frac{3}{4}$ cwt., and broke with a little more, with bearings 2 feet 6 inches apart; the bar broke with 9 cwt.

4. Shropshire Iron.

1. Best melting iron, and chiefly in grate fronts and fine castings.

2. Second ditto best for bridges.

3. Mixing iron is strongest, but will not run fine.

4. Hard iron will not melt; is used for common bar iron.

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5. Twisted.

A cast-iron bar, one inch square, fixed at one end, and having 631 lbs. suspended by a wheel, two feet diameter, fixed at the other end, will break by the twist. Some bars require 1,000 lbs.

The strength to resist the twisting strain is the cube of the like lateral dimensions.

---

6. **Table** showing the weight of one foot in length of **Cast-iron Pipes**, from $2\frac{1}{2}$ inches to 15 inches diameter, and from $\frac{3}{8}$ to $\frac{5}{8}$ in thickness.

Bore.	3 Eighths.		½ Inch.		5 Eighths.	
	lbs.	*oz.*	*lbs.*	*oz.*	*lbs.*	*oz.*
2½	10	2	14	4	18	–
3	11	15	16	8	21	6
3½	13	11	18	13	24	5
4	15	7	21	3	27	4
4½	17	4	23	5	30	3
5	19	–	25	15	33	2
5½	20	12	28	4	36	1
6	22	9	30	10	39	1
6½	24	5	33	-	42	–
7	26	1	35	5	45	–
7½	27	13	37	–	47	14
8	29	10	40	1	50	13
8½	30	7	42	7	53	12
9	33	3	44	12	56	12
9½	34	14	47	2	59	10
10	36	11	49	8	62	10
10½	38	7	51	13	65	9
11	40	3	54	3	68	12
11½	42	–	56	10	71	7
12	43	12	59	–	74	10
12½	45	8	61	5	77	6
13	47	5	63	10	80	5
13½	49	1	66	–	83	4
14	50	12	68	5	86	3
14½	52	10	70	–	89	2
15	54	6	73	1	92	1

7. Malleable Iron.

A wrought-iron bar, 50 feet long, heated from 20 to 80 degrees, lengthens only ¼ of an inch.

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8. Experiments on Malleable Iron.

By *A. Duleau.*

Results.

1. Upon a solid, having the section a rectangle.
   1. Laid on two supports, and loaded in the middle. The bending or curvature is in proportion to the weight, the cube of the length, and inversely as the breadth and cube of the thickness.
   2. Loaded upon the end.

      The weight capable of bending is in the ratio of the breadth and cube of the thickness, and inversely as the square of the length.

2. Upon a solid, the section a circle.
   1. Laid on props.

      The bending in the ratio directly as the cube of the length, and inversely as the fourth power of the radius.

   2. Loaded on end.

      The weight capable of bending, in the direct ratio of the fourth power of the length, and inversely of the square of the length.

3. System of separate pieces tied together.

   The resistance as the difference of the cubes of total thickness of all the pieces to those of the void.

4. Hollow cylinders.

   The resistance of a square and round tube is in the ratio of the difference between the fourth power of the sides, diameters, exterior and interior.

5. A solid cylinder, twisted, or torsion.

   Angle of torsion is the direct ratio of the length of the cylinder, of the weight applied,

and of the arm of the lever, and in the inverse ratio of fourth power of the diameter.

6. Hollow tubes.

The angle described by the moveable extremity, in turning upon itself, is proportional to the difference of the fourth power of the diameters, exterior and interior.

Square prism proportional to fourth power of side of section.

---

9. Malleable Iron Rails.

These were tried at the Wallbottle Colliery near Newcastle-on-Tyne in the year 1805, by Mr. Nixon. They were square bars two feet in length, joined by a half-lap joint with one pin; one of the rails projecting beyond the adjoining rail. The use of them ceased, because the narrowness of their surface cut the periphery of the wheel, and they were superseded by cast-iron rails with broader surface. Malleable iron rails were introduced in the Earl of Carlisle's Collieries on Tindale Fell in the year 1808; but not extensively till 1815.

Cast-iron rails were first used in 1738; but the wooden rails brought by the colliers in back-carriage from the New Forest in Hampshire till it was exhausted, were in use till 1780 on the short railways for carrying coals to the river Tyne from the adjacent collieries.

---

10. Number of Blast Furnaces.

Shropshire - - - - - -	34	This was about the number in the year 1820.
Staffordshire - - - - -	64	
South Wales - - - - -	56	
Yorkshire - - - - - -	——	*Sic in orig.*
Lancashire - - - - - -	——	
North Wales - - - - -	6	
Scotland - - - - - - -	——	*Sic in orig.*
Derbyshire - - - - - -	——	

11. Result of Investigation—Suspension Bridge. By *Davies Gilbert.*

The greatest span of a catenary arch, capable of being formed by iron or steel, on the supposition of these metals supporting the greatest degree of tension theoretically assigned:—

If the tenuity of iron be taken at 50,000 lbs. for a square inch, and the specific gravity of iron at 7·8, the modules of tenacity will be 14,814 feet; put this equal to 6, in the expression for a maximum; then y will be found equal 9,817 feet, and consequently the whole span as $2y = 19{,}634$ feet, about 3·7 miles, but then $x = 66{\cdot}29$ feet, or 1·25 miles.

Steel being supposed to have 3 times the tenacity of iron, will extend their movements threefold. When x and y are equal to each other, they will be 1·16 very nearly, a being unity, and $z = 1{,}91$ t.

N.B. y, being half the chord or span = ordinate.
x, being the versed sine or abscissa.
z, length of chain, or periphery of curve, between its apex and point of section by the ordinate or chord line.

Deduction.—Points of suspension cannot be too lofty.

1.	2.	3.	4.		5.	6.	7.	8.
Horizontal distance between the points of support.	Length of curve or chain between the points of support.	Axis of curve or versed sine of chain.	Angle nearly between horizontal line and curve at point of support.		Tension or strain on each chain by its own weight at either point of support.	Tension or strain on the 16 chains, by their own weight at either point of support.	Weight of one chain.	Weight of the 16 chains.
Feet.	Feet.	Feet.	°	′	Tons.	Tons.	Tons.	Tons.
560	565·6	35	14	0	20·87	333·9	10·10	161·6
560	567·5	40	15	54	18·5 3	296·5	10·13	162·1
560	569·5	45	17	52	16 ·57	265·1	10·17	162·7

The above Table, calculated by James Jardine, civil engineer, Edinburgh, in March 1821, at my request, for the Menai Bridge, &c.

12. Iron Bridges, Weight of.

	Feet.		Tons.
1776.—Colebrook-dale	100 span		378
1796.—Buildwas	130 „		170
Sunderland	236 „	Cast	220
Add, wrought iron			40
Total			260
Bonar	150 „		180
Craig Ellachie	150 „		150

	Feet.
Menai Bridge, if an arch of cast-iron, - span	500
Diameter of circle	1,102

of which, Arch would contain 54 degrees.

		Tons.
Centre, Total Weight	Wood	589
	Iron	16
		605
Of this upon the 1st frame		121
Remains to be suspended		484

N. B.—A square inch bar of iron will sustain 27 to 30 tons.

	Tons.
Total weight of iron	3,487
Of this, upon 1st frame	1,743
To be suspended	1,744
Of this, ribs	933
Upon 1st frame	200
To be supported	733

[*See* Plate 77.]

STRENGTH OF VARIOUS SUBSTANCES.

1. Bodies may be crushed.

Gauthey, from numerous experiments, says that a pillar of hard stone of Givry, whose section is one foot, will bear 664,000 lbs.; that its extreme strength is 871,000. The soft Givry stone, weakest, bore 187,000; strongest, 311,000. A pillar of All Saints, at Angers, 24 feet long, 11 inches square, is loaded with 60,000 lbs., not one-seventh of what is required to crush it.

Good brick will carry	320,000 lbs.
Good chalk	9,000 „

2. Tried by W. Reynolds, of Ketley.

Cast-iron gun-metal, a cube of one-fourth of an inch requires 22,400 lbs. to crush it; or soft grey cast-iron, same dimensions, required 8,960 lbs. to crush it.

Pitet and Parent say, that it requires something more than 60 lbs. upon every square inch of sound oak to crush it.

Fir, although it will not suspend so much, will support twice as much as oak, as a pillar.

On the centres at Orleans, some pieces of oak were loaded with upwards of two tons upon every square inch of scantling.

Perronet says, that stone got near St. Max, which weighed 144 lbs. per cubic foot, required 7,350 lbs. to crush a piece one inch square, and two inches high; and that stone got from Saillons, weighing 165 lbs. French cubic foot, required only 1,825 lbs. to crush an equal scantling.

3. Bodies may be pulled asunder.

Absolute cohesion is proportional to the area of the section, whose texture is a perpendicular to the extending force.

4. A Square Inch will Suspend:

By *Emerson.*

	lbs.		lbs.
Iron	76,400	Red Fir	5,000
Brass	35,600	Alder, Ash, Birch	4,290
Hempen rope	19,600		
Oak Box	7,850	Freestone	914
Walnut	5,360	Lead	430

By *Robinson*.

	lbs.		lbs.
Cast-iron - -	{ 42,000 / 49,000	Soft Bar Steel -	120,000
Bar, ordinary ditto	68,000	Block Tin - -	150,000
Bar, Swedish -	84,000	Lead - - - -	8,600

5. PROPORTIONAL STRENGTH, by *Emerson*.

Box, yew, plumtree, oak - - - - -	11
Elm, ash - - - - - - - - - - -	$8\frac{1}{2}$
Walnut, thorn - - - - - - - - -	$7\frac{1}{2}$
Red fir, holly, elder, plane, apple-tree -	7
Birch, hazel, cherry-tree - - - - -	$6\frac{2}{3}$
White fir, alder, asp, willow - - - -	6
Iron - - - - - - - - - - - - -	107
Brass - - - - - - - - - - - - -	50
Lead - - - - - - - - - - - - -	$6\frac{1}{2}$
Fine freestone - - - - - - - - -	1

Mr. *Banks*.

Oak one inch square, and one foot long, bore 660 lbs.; it was much bent, and 2 lbs. more broke it. *N. B.* This was the weakest part of the dry heart of oak.

The strongest he tried broke with -	974 lbs.
The worst deal - - - - - - - -	460 „
The best ditto - - - - - - - -	690 „
Weakest cast-iron - - - - - - -	2,190 „

6. Mr. *Rennie*'s Letter to Mr. *Gladstone*.

30 May 1821.

Mr. Gladstone found that a round piece of oak, a quarter of an inch diameter, carried 1,300 lbs. without breaking; 1,302 lbs. broke it.

A rod of iron, of same diameter, 3,290 lbs.; 3,318 lbs. broke it. Iron 2 ½ times therefore, but 8 ½ times heavier.

But wood must have iron fastenings, and cannot be got uniformly clear and strong.

Mr. Rennie's Experiments in 1808:—A rod of iron, a quarter of an inch, carried 4,860 lbs., which is four times the strength of oak.

On the whole, thinks that if wood is employed, using compression is, upon the whole, preferable. City, Schauffhausen, Wiebeking.

7. MODULUS of ELASTICITY in Thousands of Feet; from Supplement Encyclopædia Britannica.

	Feet.		Feet.
Iron and Steel - -	10,000	Fir - - - - - -	10,000
Copper - - - - -	5,700	Elm - - -	8,000
Brass - - - - -	5,000	Beech - - -	8,000
Silver - - - - -	3,240	Oak - - -	5,060
Tin - - - - - -	2,250	Box - - -	5,050
Crown Glass - -	9,800	Ice - - - -	850

In wood or iron, a round column or square pillar will not be bent by any longitudinal force applied to its axis, which it can withstand without being crushed, unless its length be greater than twelve or thirteen times its thickness; nor of stone, unless forty or forty-five times. Therefore a piece of timber or iron should be at least as many inches in thickness as it is feet in length.

Modulus of elasticity found by this analogy:—As the diminution of the length of any substance is to its length, so is the force that produced that diminution to the modulus of elasticity.

An oak beam 8 feet long and 6 inches square, when supported at each end—Query, What will break it? N. B.—660 lbs. will break an inch square, supported at each end.

Rule:—Multiply the breadth into the square of the depth, and divide by the length; multiply by the weight, which might be a constant quantity.

$$\frac{b\,d^2}{l\,w} = \frac{B\,D^2}{L\,W};\ \text{here } W = \frac{B\,D^2\,l}{b\,d^2\,L}:$$

In this case gives $W = \frac{b \times b^2 \times 660}{1 \times 12 \times 8} = 17820$ lbs.

Length as above, breadth three inches, weight 17,820 lbs.—Query, depth?

From general equation $D = \sqrt{\frac{b\,d^2\,L\,W}{B\,w}} =$

$$\sqrt{\frac{1 \times 1^2 \times 8 \times 17820}{3 \times 1 \times 660}} = 8{\cdot}45 \text{ inches, nearly.}$$

Bar eight feet long, four inches depth, weight 17,820 lbs.—Query, breadth? (N. B.—Cast-iron.)

$$B = \frac{b\,d^2\,L\,W}{D^2\,l\,w} = \frac{1 \times 1^2 \times 8 \times 17820}{4^2 \times 1 \times 2190} = 4{\cdot}07 \text{ inches.}$$

An oak bar, one inch square, supported at both ends—Query, What length at which it will break by its own weight?

$l = 1$ $W = \frac{2}{3}$ of a lb. $u = 660$. Then $L = \sqrt{l \times \frac{l \times (w + 2u)}{w}} = 57{\cdot}45$ feet, nearly.

An iron bar, one inch square, supported at both ends—Required the length at which it breaks by its own weight?

Here, l as before; $u = 2190$; $w = 3$; Hence, $L = \sqrt{l \times \frac{l \times (w + 2lb)}{w}} = 38223$ feet, nearly.

ARCHES OF MASONRY.

1. Arches.

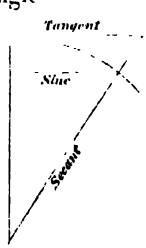
If we divide the span of an arch into four equal parts, and add to the weight of one of the middle parts one-sixth of its difference; from the weight of one of its extreme parts, we shall have a reduced weight, which will be to the lateral thrust as the height of the arch to half the span.

The abutment must be higher without than within, by a distance which is to its breadth as the horizontal distance of the centre of gravity of half the arch from the middle of the abutment is to the height of the middle of the key-stone above the same point.

In order that an arch may stand without friction or cohesion, a curve of equilibrium proportional to all the surfaces of the joints must be capable of being drawn within the substance of the blocks.

2. Weight and Pressure.

As the side of any right-angled triangle
Is to the sine of its opposite angle,
So is any other side
To the sine of its opposite angle.



As the sine of any angle
Is to its opposite angle,
So is the sine of any other angle
To its opposite side.

As the tangent of the angle of the section at the crown of the arch
: weight of that section,
: : secant of the angle of any section
: horizontal push against the abutment.

The logarithm secant of an angle may be had by subtracting the co-sine of the angle from 20,000.

The index of the logarithm is always one less than the number of integers in the number of places in whole numbers, and the whole numbers are always to be one more than the index is in integers.

As the rad. of arch in feet, say 30·702 -	1.488,014
Is to the radius (viz. 90°) - - - -	10,000,000
So is half the breadth of the voissure, 98,765	9.994,608
To the sine of half the opposite angle -	1.188,014

	°	′	″
As half the angle of the voissure - - -	1	50	23
	1	50	23
Angle of the voissure	3	40	46
Angle of two ditto -	7	21	32

As the tangent of the angle of the section at the crown of the arch, say	° ′ ″ 3 40 46 -	8,802,563
Is to the weight of that section - - -	Tons. 11·56,367 -	1,0620800
So is the tangent of the angle - - -	° ′ ″ 7 21 22 - -	9,1109208
To the weight of that section - - -	23·1603	
Deduct weight of 1st section - -	11·5367	
Remaining weight of 2d section - -	11·6236	

As the tangent of the angle of the section at the crown of the arch, say	° ′ ″ 3 40 46 - -	8·8082560
Is to weight of that section	Tons. 11 5637 - -	1·0620800
So is the secant of ditto - - - -		10·0008837
		11·0629637
		8·8082563
To the push of that section against abutments - - - - - -		2·2547074
Viz. - -	Tons. 1797	

3. Head of Water.

To find the Head of Water at Bridges:—

Add ⅟₁₀ to the breadth of the river, and divie

the sum by the water-way under the arches from the square of the quotient.

Subtract unity; multiply the remainder by the square of $\frac{1}{8}$ part of the mean velocity of the river for the fall in feet.

4. CENTERINGS.

Perronet states, that upon the centres of the bridge of Orleans some pieces of oak carried two tons upon every square inch.

	Feet.	Tons.
Colebrook-dale Bridge	100	378
Buildwas	130	174
Sunderland	236	220
And of wrought iron		40
Bonar	150	180
Craig Ellachie	150	180

5. PILE-DRIVING.

Piles 10 inches square, driven 10 feet deep, until 20 strokes of a ram 4 cwt. falling 4 feet do not drive the pile one inch.

6. LIME.

In Shropshire, to produce 3,000 tons of lime, 5,000 tons of stone will be required, and 1,428 tons of coal.

7. PARKER'S CEMENT.

Analysis of Stone used by *Francis* and *White*.

100 grains of stellated Ludos Hermonte, dried at 300°, is composed of

	Grains.
Carbonic acid	29
Water	3
Lime	35
Silica	17·75
Alumina	6·75
Magnesia	·50
Oxide { Iron black	6
Oxide { Manganese, brown	1
Loss	1
	100

8. ANALYSIS OF HARWICH STONE.

Carbonate of lime	70
Aluminous earth	24
Iron	6
	100

9. ROWLEY-RAG STONE.

Rowley Rag. in 100 parts		
	Siliceous earth	32·5
	Argil	47·5
	Iron	20
		100

RAILROADS.

1. RAILROADS.

Josiah Jessop found, by experiment, that a horse weighing 10 cwt. worked with difficulty over a pulley 504 lbs.

This required 11 men's equally strong exertions;

And that the friction on a level well-laid railway is equal to a rise of $4\frac{1}{2}$ inches in a chain.

With a rise of $1\frac{1}{2}$ inches in a chain, a horse takes 6 to 8 tons; that is, 30 feet rise in a mile.

A horse weighing 10 cwt. has a force of 160 lbs.; 12 lbs. will track a ton upon a well-laid level railway;

Thus 13 tons 7 cwt. is the work of a horse, or 10 tons of goods, exclusive of waggons.

2. RAILWAY WAGGONS.

Formerly at Newcastle, each was loaded with 4 tons.

This was found inconvenient.

Therefore, from 1 to $1\frac{1}{2}$ tons, inclusive of waggons, is laid upon 4 wheels' weight of waggons, from 10 to 12 cwt. size; length, 6 feet; breadth, 4 feet; depth, $1\frac{1}{2}$.

Cost of railroads, from £. 3,000 to £. 5,000 per mile.

Cost of canals, from £. 6,000 to £. 9,000 per mile.

Horse works 3 times as much on a canal as on a railway.

Query?	On a canal, 3 men, One man and a boy, Or, boatman's wife,	On a railway, one.

Upon a well-constructed road, where the tolls are moderate, cost on a cart $1\frac{1}{2}d.$ per ton for 100 yards.

	d.	
Running a four-horse coach	$1\frac{1}{2}$	100 yards.
Ditto - chaise	$1\frac{1}{4}$	„
Ditto - a noddy	1	„

	£.	s.	d.
4 rails, each 42, at 12 per	–	18	–
4 stones for ditto - 1*s.* 3*d.*	–	5	–
Plugs and nails	–	1	–
Land, £. 60 per acre	-	2	–
Forming road	-	2	–
Fencing	-	3	–
Per yard of double railway	£. 1	11	–

Distance, 2 Miles.

Pinkie single railroad.	1st	$\frac{1}{3}$	descends at 1 in 72
	2d	$\frac{1}{3}$	nearly level.
	3d	$\frac{1}{3}$	rises 1 in 700.

One horse draws 4 waggons, with $1\frac{1}{2}$ tons each; waggon weighs about 12 cwt. Horse makes 5 trips a day.

Distance, 4 Miles.

Hinton single	First furlong descends one in	125
	Last mile	240
d.	Rest nearly level.	

Good horse draws four waggons with $1\frac{1}{2}$ tons each; waggon weighs about 11 cwt.; each horse makes five trips a day, of 10 hours.

MISCELLANEOUS ARTICLES.

1. Ship,—by *Emerson.*

That any sail may have the greatest force to move a ship forward, it might be placed between the point of the wind and the ship's way, that the tangent of the angle it makes with the wind may be twice the tangent of the angle it makes with the ship's way.

When the rudder is set to an angle $54\frac{1}{2}^{\circ}$ with the keel, it has the greatest force to turn the ship and make her answer the helm.

The water should come freely and directly upon the rudder, so as that she should not be too short between midships and stern, and must draw more water abaft than afore.

2. Copper.

Copper sheets for sheathing ships are in sheets containing 8 superficial feet, and weigh 14 lbs.

Price - - - - 16*d.* per lb.
One foot super. weighs 1 lb. 12 oz.
Or at the rate of 28*d.* per foot super.

3. Tides.

The high water transmitted from the tide in the Atlantic reaches Ushant between three and four hours after the moon has passed the meridian, and its ridge stretches north-west, so as to fall a little south of the coast of Ireland. This wave, soon after, divides itself into three, one part passing up the British Channel, another ranging along the west side of Ireland and Scotland, and the third entering the Irish Channel. The first flows at the rate of about 50 miles an hour, and washes the Nore about 12 at night. The second moves with more rapidity; at 6 it has reached the north of Ireland; at 9, the Orkney Islands; at 12, it extends from the coast of Buchan, eastward to the Naze of Norway; and in 12 hours more it reaches the Nore, where it meets the morning tide that left the mouth of the Channel eight hours before.

4. Ramsgate Harbour.

Length of eastern pier	2,000 feet.
„ western ditto	1,500 „
Extent into the sea	800 „

Cost said to be £.600,000.

Area	46 acres.
Entrance	240 feet.

500 to 800 vessels have entered annually.

See further, page 116, *n.*

5. Carriage Wheels.

Usual height extends to 5 feet 8 inches; that is to say,

	ft.	in.	
For 8 spokes -	3	2	Spokes should not be more distant in the fellies than 15 inches.
10 ditto -	4	6	
12 ditto -	5	4	
14 ditto -	5	8	

Breadth between wheels 4 ft. 8 in. or 4 ft. 10 in.
Ditto waggons or carts 5 ft. 2 in.

Coachmakers' rule, never to allow the fore wheels to have but two spokes less than the hind ones.

Dr. Brewster says the iron rims or plates should never be less than 3 inches in breadth.

A wheel of 8 feet diameter has somewhat more than twice the advantage in overcoming obstacles of a wheel of 2 feet; therefore with wheels of any determinate diameter, it will require wheels of four times that diameter to draw the same carriage over the same obstacle, with half the power; also in ascending inclined planes, the moving power acts, not only against the *vis inertiæ*, which is always equal to the absolute gravity of the load, but also against its relative gravity, which increases with the inclination of the plane; therefore the higher the axle is removed from the plane, the farther is the centre of gravity removed out of the perpendicular line of support, so that the lower the wheel, the less is the relative gravity of the carriage; hence of different sized wheels, every thing else equal, the low wheels would be drawn upon a smooth inclined plane more easily than the higher ones, though on a smooth horizontal plane the latter would be drawn easier than the former; on passing down inclined planes, large wheels urge the carriage forward.

Whenever wheels exceed 4½ feet radius, then the height of that part of the horse to which the traces should be attached will incline to the horizon. It appears that wheels to be drawn by horses should not have a radius more than 3 feet or less than 21 inches.

That is more than 6 feet diameter or less than 3½ feet.

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6. TABLE, shewing the Angles which different Clivities (Slopes) of a Road make with the Horizon, by Mr. *Macneill.*

Perpendicular.	Horizontal on Base.	Angle of the Clivity (Slope) with the Horizon.	Perpendicular.	Horizontal on Base.	Angle of the Clivity (Slope) with the Horizon.
1	1	45° 0′	1	20	2° 51′
1	2	26° 34′	1	28.63	2°, —
1	3	18° 26′	1	30	1° 54′
1	4	14° 2′	1	40	1° 25½′
1	5	11° 18′	1	50	1° 8½′
1	6	9° 27′	1	57.28	1°, —
1	7	8° 7′	1	60	0° 57½′
1	8	7° 7′	1	70	0° 49′
1	9	6° 20′	1	80	0° 42½′
1	10	5° 42′	1	90	0° 38½′
1	15	3° 48′	1	100	0° 34½′

Appendix (Y. 2.)

COMPARATIVE TABLES of European Weights, Measures, and Monies of Accompt; with Observations on Elementary Measures, and on Monies of Accompt.

Comparison of Weights.

		English Grains.	Number equal to 100 lbs. Avoirdupois.
England	Pound Avoirdupois	7,000	100·000
Amsterdam	Pound	7,625	91·803
France	Livre Usuelle	7,717	90·708
	Kilogramme	15,434	45·354
Munich	Pound	8,656	80·868
Prussia	Pound (2 Cologne marks)	7,218	96·979
Rome (Modern)	Libbra	5,234	133·741
Rome (Ancient)	Pondo or Libra	5,174	135·291
Russia	Pound	6,318·5	110·785
Spain	Libra	7,101	98·577
Sweden	Pound (32 Lods)	6,563	106·658
Vienna	Pound	8,645	80·972

Comparison of Elementary Measures of Length.

		English Inches.	Number equal to 100 English Feet.
England	Foot	12·00	100·000
Amsterdam	Foot	11·41	105·171
Rhineland	Foot	12·35	97·166
France	Pied de Roi	12·78	93·896
	Metre	39·37	30·480
Munich	Foot	11·37	105·540
Prussia	Rhineland Foot	12·35	97·166
Rome (Modern)	Foot	11·72	102·389
Rome (Ancient)	Pes	11·60	103·448
Russia	Foot	13·75	87·272
Spain	Foot	11·12	107·913
Sweden	Foot	11·68	102·739
Vienna	Foot	12·45	96·385

In the above table of Elementary Measures of length, the agreement of all Europe in referring to the human foot as a basis of measurement, is very remarkable;—and not less useful than remarkable, as furnishing an approach to universal language; so that when we read of any length expressed in Feet, we know it cannot err in excess beyond a seventh part, nor in defect above one-nineteenth part of English measure; proportions which approximate sufficiently to satisfy the mind for general purposes, and to produce the great advantage of not interrupting any train of thought by the necessity of extraneous reference, unless in cases which demand regular investigation and precision.

As the shortest of the enumerated European measures of length estimate the human foot as exceeding eleven inches English, we may conclude that all have had their origin in the ancient Roman foot, which was to our own as eleven inches six-tenths (11·6); exceeding the usual length of a human foot considerably, and perhaps taken from the *Footstep mark* of a sandal or clumsy shoe. Five of these feet made the Roman pace (*Passus*), and one thousand paces (*Mille passus, Mille passuum, Milliare*) the Roman mile, about one hundred and forty-nine yards shorter than our English mile.

In speaking of the pace (*Passus*), a dangerous mistake has become current, in confounding it with the half-pace, or step (*Gradus*); while the pace is the passage (*Passus*) of a lifted foot to its next resting-place in walking. This distinction ought to be carefully observed, as considerable danger of a national blunder impends over us; books of some reputation which teach surveying, especially military sketching, having given their authority to the error.

Far more ancient than the Roman foot and pace is the Scriptural Cubit, which Moses, "learned in all the learning of the Egyptians," no doubt adopted from that nation, to which has always been ascribed the origin of mensuration. Moses had also learned from them the still more useful art of expressing words by characters which denoted sounds (phonetic characters), which from him produced the written languages of Palestine, of Greece and of Italy, and derivatively of all nations whose alphabet commences with A and B.

Those who believe that hieroglyphics denote any distinct meaning as a written language thus have to consider, that if they existed before the time of Moses, they were then accompanied by a more convenient mode of expression. But they did not exist till after the time of Moses, because the earliest monuments of Egyptian greatness, the Pyramids, exhibit no hieroglyphics; and as phonetic characters did not cease to exist thenceforward, those cumbrous emblems could not have been invented for the purpose of expressing language, but were invented for some other purpose. The result is, that they were afterwards invented by the priests for the purpose of religious mystery; which, in conferring power and wealth on that numerous body of men, coincided with the seeming policy of the state. For the productive power of the soil of Egypt, irrigated by the Nile, was such that multitudes were nourished at small expense of labour; so that had not artificial labour been created, the well-fed, half-idle population would not have failed to turn their thoughts to

politics and sedition. Huge buildings, of no other value, were perpetually in progress to prevent this evil, which, with the great expense of the religious and military castes, retained a very numerous population in a wholesome state of subordination to the laws.

If the practice of public buildings commenced with the Granaries of Joseph, when he re-modelled the Egyptian government and people * (1,700 years before Christ), and endured till the extinction of the Ptolemaic dynasty (a few years before the Christian æra), this policy seems to have been systematically maintained. From that time imperial Rome, and afterwards Constantinople, consumed the superfluous corn and other products of Egypt; a nation which has ever since been under such foreign domination as has more than sufficiently precluded superfluity among its native inhabitants.

The Cubit, or elbow measure, is the height of an extended middle finger, when the bent elbow rests on a flat surface; and the sacred cubit exceeds the usual measure of the actual cubit so taken. Dr. Arbuthnot's computation estimates the sacred cubit at one foot and nearly ten inches (1·9·888), but Sir Isaac Newton, from the Pyramidographia of Greaves, fixes it indubitably at (1·8·628), one foot eight inches and nearly two-thirds.

It is a curious fact, that while the Numeration of the Romans was decimal (by tens), they always divided their unit or integer into twelve parts; so that their *uncia*, is equally the origin of the words "ounce" and "inch," while their year, day and night equally exhibit a duodecimal division; and the imitation of this in an after-age was carried so far, that the Norman scribes, who compiled Domesday book, oftener than once inform us, that the Saxons reckoned 120 (twelve tens) to the 100.

It is not easy to believe that the English foot (rude as we must suppose it to be in its origin) is founded on the Roman ounce weight: which renders the accidental coincidence the more extraordinary, in that 1,000 Roman ounces (Avoirdupois ounces) of water should exactly fill a cubic foot. Exceedingly convenient has this been in Tables of specific gravity, which thus assume a decimal form; and another instance of accidental analogy of an English square mile, with the geographical square mile, (assimilating it to a universal measure,) is explained in page 92 of this volume.

A modern attempt in France to alter established weights and measures appears in the foregoing Tables, and has been so far successful, that it demands notice in this place. During the fervour of the Revolution, the French Convention acted on the simple principle, that whatever was established ought to be overthrown; so that the number of days in a week and in a month, the names of the months, and the date of the Christian æra were equally exploded; and the democrat philosophers did not fail to claim a decimal division of weights and measures. A Decree to this effect was

* See the distinct narrative of this remarkable fact (the most remarkable in history) in the Book of Genesis, Chapters XLI and XLVII.

published in April 1795; but it was not successful in superseding the customary divisions of all commodities into halves and quarters; and the inconvenience was found to be so great, that in the year 1812, Buonaparte legalized a *Système usuel*; which has since been established by a Royal Decree in the year 1816, as the only legal system. But the Metre, or philosopher's unit of measure, must be so far noticed, as to say that it is as eleven to ten compared to an English yard; in other words, that by adding one-tenth to any number of metres, you obtain the same measure in English yards; by deducting one-eleventh from a number of yards, you obtain the equivalent number of metres.

An attempt to improve English weights and measures took place in the years preceding 1826, when at last the Legislature sanctioned the recommendation of certain persons to whom the investigation had been confided by a Royal Commission. They did not indeed alter the established long measure; but what Board, what Committee of Inquiry can be expected to report, that the inquiry has been useless, inasmuch as alteration would be injurious? The respectable corn measure of England, which dated from the time of Henry III. (600 years since) was the victim on this occasion, and the legal bushel throughout the south of England became illegal, being superseded by a bushel increased by a thirty-second or thirty-third part, the exact difference not being easily appreciable. The *negative* result of the law has been, that after much expense incurred by the counties and towns which were constrained to purchase costly standard measures, these have never once been employed, the ancient bushel remaining in use universally as before; the *positive* result having been, that all previously acquired knowledge of the great national question of the Corn Laws, was lost to the possessor of it and to the public, because the Official Returns before the year 1826 cannot now be easily compared with the Returns of Price, Import and Export since that time; and as these Returns no longer represent the bushel in current use, every investigation of the Corn Law question is involved in a similar degree of confusion; while the new law can only be enforced in measuring commodities subject to the duties of Customs or Excise.

Comparison of Road Measures of Length.

		English Yards.	Number equal to 100 English Miles.
England - -	Mile - - - - - -	1,760	100·000
	Mile geographical - - -	2,025	86·913
Ireland - -	Mile - - - - - -	2,240	78·571
Scotland - -	Mile - - - - - -	1,984	88·709
France - - -	Kilometre - - - - -	1,093	161·024
	Post-League of 2,000 Toises -	4,263	41·285
	Marine League ($\frac{1}{20}$th of a degree)	6,076	28·966
Germany - -	Mile geographical - - -	8,101	21·725
	Mile long - - - -	10,126	17·381
	Mile short - - - -	6,859	25·659
Holland - -	Mile - - - - - -	8,101	21·725
Prussia - - -	Mile - - - - - -	8,237	21·367
Rome (Modern) -	Mile - - - - - -	1,628	108·108
Rome (Ancient) -	Mille passus - - - -	1,611	109·249
Rome - -	Mile geographical - - -	2,025	86·913
Russia - - -	Werst - - - - - -	1,167	150·814
Spain - - -	League common - - -	7,416	23·732
	League judicial - - -	4,635	37·972
Sweden - -	Mile - - - - - -	11,700	15·042

Comparison of Land Measures, of Area.

		English Square Yards.	Number equal to 10 English Acres.
England - -	Acre - - - - - -	4,840	10·000
Scotland - -	Acre - - - - - -	6,150	7·869
Ireland - - -	Acre - - - - - -	7,840	6·173
Amsterdam - -	Morgen - - - - - -	9,722	4·978
France - - -	Hectare - - - - - -	11,960	4·046
Prussia - - -	Morgen - - - - - -	3,053	15·853
Rome (Modern) -	Pezza - - - - - -	3,158	15·196
Rome (Ancient) -	Jugerum - - - - - -	3,093	15·648
Russia - - -	Dessetina - - - - - -	13,066·6	3·704
Spain - - -	Fanegada - - - - - -	5,500	8·800
	Arranzada - - - -	4,623	10·469
Sweden - - -	Tunneland - - - - -	5,900	8·203
Vienna - - -	Joch - - - - - -	6,889	7·025

TABLE of MONIES of ACCOMPT; their Value expressed in Pennies (Pence) Sterling, according to the Mint Price of Silver in England; viz. 5*s.* 2*d.* per oz. Standard.

		Pence.
England - - -	Pound sterling - - - - - -	240
Scotland - -	Pound, Scots - - - - - - -	20
Amsterdam - -	Rix-dollar - - - - - - -	52·54
	Florin (old) - - - - - - -	21·
	Florin (new) - - - - - -	20·72
	Pound, Flemish - - - - - -	124·32
Berlin - - -	Pound, Banco - - - - - -	47·25
	Rix-dollar current, or Thaler - - -	36·
France - - -	Livre Tournois - - - - - -	9·58
	Franc (new system) - - - -	9·70
Munich - - -	Gulden, or Florin - - - - - -	21·
Rome - - -	Scudo, or Crown - - - - - -	52·05
	Scudo di Stampa d'Oro - - -	79·37
Russia - - -	Ruble - - - - - - - - -	38·50
Spain - - -	Real of old Plate (of 34 Maravedis Plate)	4·88
	The Spanish Dollar - - - -	51·79
Sweden - - -	Rix-dollar - - - - - - -	55·41
Vienna - - -	Florin - - - - - - - - -	25·20

Previously to the year 800, Charlemagne established throughout his extensive empire a Pound of silver (Troy weight), dividing this Pound or Libra of silver into 20 Solidi, or shillings, each shilling into 12 denarii, Deniers or pence: a method of computation which was also adopted in England in the time of Edward the Confessor, and afterwards in Scotland. But although the division of the libra or pound into shillings and pence remains the same in the monies of accompt, the value of the pound is become very different in proportion as it has been depreciated by the necessities or dishonesty of various governments.

Thus the English pound is fallen in value to one-third (from 62 to 20 shillings); the Scottish pound to 20 pence, the French Livre (libra) to 10 pence; the Libra of Spain differs in various provinces from 27 to 48 pence English; and in most of the states of Italy the Lira expresses about 8 pence English. The English penny has always been divided into halves and quarters, called the halfpenny and farthing (fourth-ing); and although the pound sterling has nearly superseded the Scottish pound in that ancient nation, their shilling (of the same value as the English penny) is still divided into twelfths; and in the last column of a money accompt is so denoted. The English mode of expressing our own halfpenny, farthing and three farthings is not a little troublesome, as requiring more time in writing, and more care in reading the farthing column accurately

than the more important columns which precede it. The expression of $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$, is also inconvenient to the typographer, from disturbing the interspaces of lines, and from the minute type which is unavoidable; and it becomes worth while to consider whether such inconveniences ought not to be superseded by simply expressing the number of farthings, as of shillings and pence, without marking any denominator. Our forefathers were slow in dismissing Roman Numerals from their accompts; and when they adopted the Arabic notation, they continued to incumber the columns with useless Zeros, not considering that a Zero, being of no value unless after some other figure, ought not to be designated otherwise than by a blank (—), because the appearance of 0, inaccurately written, leads the accomptant into danger of mistaking it for a 6. A specimen is subjoined of the ancient, modern and proposed methods of expressing money accompts.

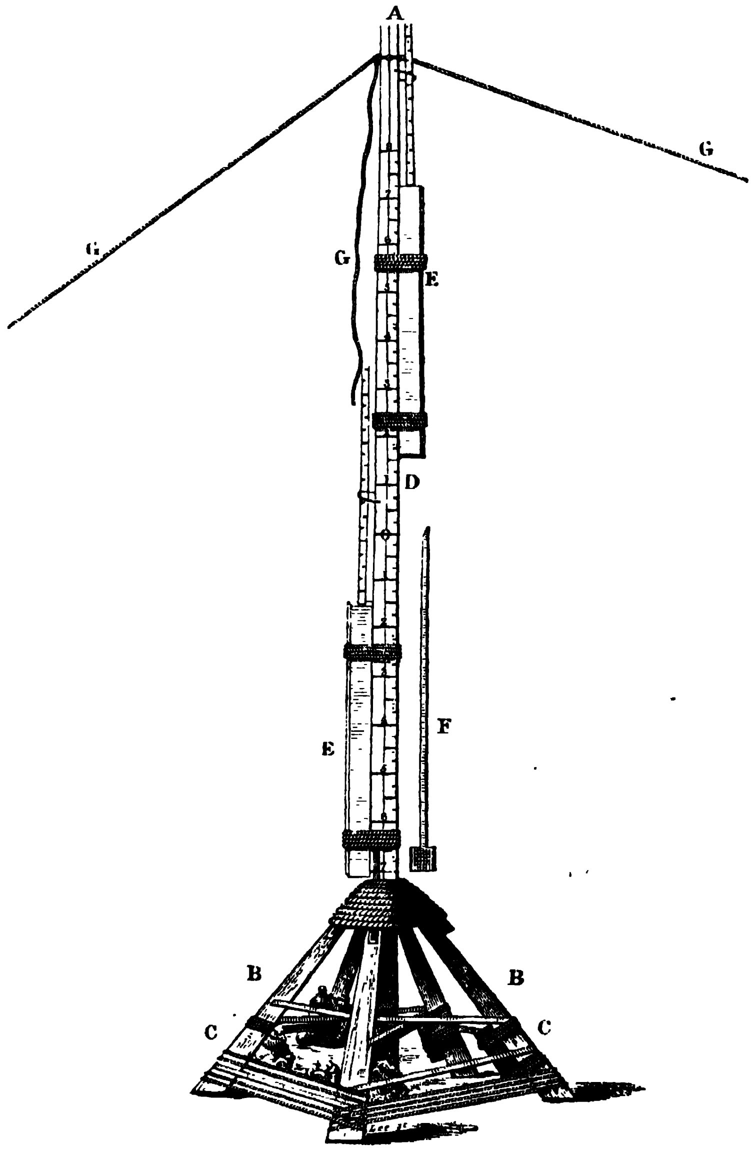
£.	s.	d.	£.	s.	d.	£.	s.	d.	
15 :	01 :	10 $\frac{3}{4}$	15 ,,	1 ,,	10 $\frac{3}{4}$	15 .	1 .	10 ,	3
22 :	16 :	07 $\frac{1}{4}$	22 ,,	16 ,,	7 $\frac{1}{4}$	22 .	16 .	7 ,	1
06 :	05 :	11	6 ,,	5 ,,	11	6 .	5 .	11 ,	
40 :	00 :	06 $\frac{1}{2}$	40 ,,	0 ,,	6 $\frac{1}{2}$	40 .	– .	6 ,	2
£. 84 :	04 :	11 $\frac{1}{2}$	£. 84 ,,	4 ,,	11 $\frac{1}{2}$	£. 84 .	4 .	11 ,	2

The figures in the last column of the proposed notation may be made rather smaller than the figures expressive of higher value, and separated from the pence by a comma, instead of the ceremony of making a cross line and denominator (2 or 4) in the fractional expression. Such abbreviation of each operation may appear unworthy of notice; but if multiplied by the number of such operations, and considering the many industrious classes of society who have daily occasion to write and keep small money accompts, the total amount of facility will resemble the effect of bringing into use a powerful machinery, with the same advantage of additional accuracy, and in an operation to which final accuracy is a quality of indispensable necessity.

J. R.

APPENDIX (Z.)

TIDE-GAUGE; communicated by *Edmund B. Westbrook*, Esq. of the COAST GUARD SERVICE, *Chichester* Harbour.



A. A stout pole, five or six inches diameter, twenty-four feet long, where the range of tide does not exceed sixteen feet.

B. Legs to support the pole, secured by stout battens or small spars, from leg to leg, and from each leg to the pole, to keep them separate; then they are connected and secured by lashings round the top and bottom of the legs, and from the legs to the heel of the pole. Cleats are nailed to the pole above the upper lashing for greater security, and to prevent its slipping upwards; then wedges driven in between the legs and upper lashing to tighten all parts.

C. C. Ballast of pig-iron or heavy stones, lashed to the under part of each leg, as low down as the ropes will admit.

D. A graduated scale on a thin slip of deal, (which hides the pole) affixed by nails to the pole. This scale indicates the height of the pole from the ground, and the exact position of the bottom of each box.

E. E. Quadrangular boxes or tubes for containing the measuring-rods; six feet long, three inches clear diameter within, made of half-inch deal, and lashed to the pole; the top of the upper box being a foot or eighteen inches above the utmost range of high-water; the bottom of the lower box being in like manner a foot or eighteen inches below the lowest range of low-water. A small gimlet-hole *only* in the bottom of each box admits the water, the level of which is preserved and indicated free from agitation. A slit of *just sufficient* dimensions at the upper end of each to admit freely the passage of the measuring-rod; thus the rod itself nearly occupies the space, and prevents an overwhelming wave filling the box, and disturbing the true level of the internal water. These upper ends take off and on, in order that the rods may be changed if broken or damaged; a spare rod should be taken in the boat at the time of observation.

F. One of the measuring-rods (represented out of its box), is made of a thin slip of deal about three-quarters of an inch wide, and three inches longer than its box; it is supported by a cork-float (three inches solid), and graduated in feet and inches from the upper to the lower end; when the cork commences floating as the tide rises round the upper box, there will then be three inches water above the bottom outside; therefore when the rod is down and the float resting dry, let the rod indicate three inches. A staple driven into the pole thirty inches above each box will receive the rod when its end is above that height, and serve to steady and preserve it from motion in a strong breeze. Press and wedge the rods down into their respective boxes, when the observation has been completed.

G G G. Represent four guys rove through as many thimbles or pullies fixed round the head of the pole. If the pole swerve, and the leeward legs sink deeper than the others, by reason of a heavy surf or strong tide, these guys attached to boats' anchors, placed out at equal angles, serve by a slight pull to restore its true perpendicular. They are better left slack, as this prevents the accumulation of sea-weed, and they are not requisite to keep the base of the pole on its original spot, that being thoroughly effected by its five or six hundred weight of ballast.

A block is always fixed under the lashing of the upper end of the legs, with a rope rove and remaining. This rope is used to sway the pole up to the stern of a boat,—to lower it on its destined spot,—and raise it again when done with.

Observations.—When the pole is legged and lashed for a temporary purpose, and intended to be used from an open beach, it should be carried down near low-water mark before the ballast is affixed; when ballasted, and the tide has risen high enough, it should be swayed up to the stern of a boat, or two (if necessary), by means of the said block and rope, and conveyed to a previously selected spot, where it has been ascertained there is six or seven feet at low-water. Avoid filling up the base with loose stones or rubbish, after the pole has been placed, as it will answer no desirable end, and prevent its being hoisted from the ground when done with: a clear sandy bottom should be selected where practicable.

Tie a knot on each of the guys fifteen or sixteen feet from their ends, to prevent unreeving; temporarily tie these loose ends to the pole to prevent their blowing about or drifting out when submersed.

Coil up the rope rove in the block, and stop or fasten it near the bottom of the lower box, that it may be got at when necessary to bring the pole in again.

The legs occupy a space of about seven feet diameter.

E. B. W.

INDEX.